

**Index of Biotic Integrity for Mine Influenced Streams; Redbird District,
Daniel Boone National Forest, 2015**



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Introduction

There is a long history of coal mining in Kentucky, including lands currently managed by the Daniel Boone National Forest (DBNF). Most mining was conducted either prior to the period of Forest Service (USFS) ownership, or more recently where the mineral estate was split from the surface estate prior to acquisition. A better understanding of stream health in watersheds with a history of mining is needed to assist resource managers in prioritizing remediation projects and other land management activities. In spring 2015, the DBNF partnered with the USDA Forest Service, Southern Research Station, Center for Aquatic Technology Transfer (CATT) to assess stream health at 13 sites on 12 Redbird Ranger District streams located in watersheds with a history of mining activity (Figure 1).

The Red Bird River is over 34 miles long and runs through the southeastern Kentucky counties of Bell, Clay, and Leslie. The river is part of the Kentucky River Basin, and forms the South Fork of the Kentucky River at its confluence with Goose Creek at Oneida, KY. For much of its course, the Red Bird River runs through the Redbird Ranger District of the DBNF. The watershed covers 125,257 acres and encompasses the 24,014 acre Redbird Wildlife Management Area.

The upstream portion of the Red Bird River watershed from its origin to Phillips Fork is privately owned and much of the area has been surface mined for coal. Downstream on Forest Service managed lands there are several locations where underground mining of private coal has occurred. In the Big Creek and Hector Branch sub-watersheds over 5,000 acres have been underground mined. Underground (deep) mining was the dominant mining technique until the 1950s when the development of large-scale excavation and transportation equipment made surface (strip) mining more efficient. Most of Kentucky's underground mines used a method called room-and-pillar mining, whereby 20 to 50 percent of the coal is left in the mine to support the overlying rock (Figure 2).

Most of the mining in Big Creek occurred between 1952 and 1962 with a couple of mines staying open until 1967. During this period the Hazard #4 coal seam was mined by various coal companies. Many of the mine portals are still open and considered abandoned. Not as much reclamation occurred as would be required under today's regulations.

Our primary goal was to compare fish and macroinvertebrate communities and stream habitat on the DBNF in streams influenced by mining with streams not influenced by mining.

Methods

Site Selections and Layout

In 2015, we completed fish, macroinvertebrate, and stream habitat inventories at 13 sites (Figure 3, Tables 1 and 2) selected from 12 streams in watersheds known to contain active or historic mining

activity. We used the data collected at these sites to compute indices of biotic integrity, and for comparison with 96 non-mine influenced site locations distributed throughout the DBNF (Figure 4).

Not much was known about the aquatic biota in the smaller streams that were affected by mining. In an effort to characterize these streams, sites were selected downstream of deep mines. At each sample site, we measured the wetted width of 1 – 2 fast water (riffle or run) habitat units and calculated the average wetted width. If the average wetted width was ≤ 3.0 m or ≥ 7.5 m, the sample length was 120 m or 300 m, respectively (Appendix A). In all other cases, sample length was 40-times the average wetted width.

From 2005-2013 we sampled 96 stream sites on the DBNF that were included in the DBNF stream monitoring program (Olsen, 2005; Krause et al., 2013). Locations for the 96 sample sites were determined by the EPA's random site selection program for the state of Kentucky (Olsen, 2005). All EPA sites had to meet two criteria: 1) watershed greater than 13 km²; 2) depth shallow enough for backpack electrofishing. The 96 EPA sites were sampled by the CATT from 2005-2013 using the same methods as used for the mine-affected sites (Krause et al. 2013).

Fish Inventory and Kentucky Index of Biotic Integrity

A four person team using a DC backpack electrofisher collected fish from the 13 sample sites in July. The team attempted to apply standard effort of approximately 1 sec/m² of wetted stream habitat, and recorded the following data: species, individual counts for adult, age-0, and voucher specimens, electrofishing length (m), time (sec), and voltage, and GPS coordinates of the downstream and upstream sample extent (see Appendix A for detailed field methods). Of the 96 EPA sites, 86 had electrofishing samples conducted. The fish collection data (species and counts) was provided to the DBNF (Jon Walker, Forest Hydrologist and Pamela Martin, Forest Fisheries Biologist) for calculation of the Kentucky index of biotic integrity (KIBI) metrics and ratings.

The fish collection methods described by Compton et al. (2003) for use in the development of the KIBI were based on KDOW (2002) and occurred from mid-March to mid-October. Of the 388 collections for KIBI development, some sites were sampled with a seine (n=78), a backpack electrofisher (n=180), or a combination of the two gears (n=130) (Compton et al. 2003). Sample sites covered all available habitat types, were 100-250 m, and had a sampling effort of 1,800-10,800 sec (Compton et al. 2003).

The recommended sampling criteria for the developed KIBI vary according to whether a stream is categorized as headwater (<6 mi² catchment area) or wadeable (>10 mi² catchment area) (Table 3). The gray area of 6-10 mi² uses best professional judgment to categorize streams located in catchments of this size (Compton et al. 2003). Two of the 13 sample sites fell into the gray area and were categorized as

wadeable, and the rest fell into the headwater category. Our electrofishing sample lengths (120-300 m) typically exceeded the recommended range (100-125 m for headwater and 100-200 m for wadeable streams) and our sample durations (462-2,181 sec) were sometimes within the recommended range (600-1,000 sec for headwater and 600-1,800 sec for wadeable streams) (Table 3).

The KIBI scores sample sites and rates their biotic integrity as Excellent (≥ 71), Good (59-70), Fair (39-58), Poor (19-38), or Very-Poor (0-18) (Compton et al. 2003). The classification thresholds were established using reference scores, where scores $> 50^{\text{th}}$ percentile were classified as having Excellent biotic integrity; 5^{th} - 50^{th} percentile were Good, and the 5^{th} percentile was trisected to have equal intervals representing Fair, Poor, and Very-Poor biotic condition (Compton et al. 2003). We followed the recommended guideline in Compton et al. (2003), where any KIBI score that falls close (± 2 points) to the classification threshold is to contain both categories (i.e. Fair/Good).

Macroinvertebrate Inventory and Kentucky Macroinvertebrate Bioassessment Index

A four person team collected macroinvertebrates using riffle sample and multi-habitat sample methods described by the Kentucky Division of Water (KDOW 2011). Macroinvertebrates were collected in May prior to fish sampling. See Appendix A and C for detailed field methods. The macroinvertebrate samples were given to the DBNF (Jon Walker, Forest Hydrologist) for identification by a contracted entomologist and then for calculation of the Kentucky macroinvertebrate bioassessment index (MBI) metrics and ratings by Jon Walker.

We used macroinvertebrate collection methods developed by Pond et al. (2003) and KDOW (2002). Pond et al. (2003) sampled headwater streams ($< 5 \text{ mi}^2$ catchment area) from mid-February through late May, and wadeable streams (~ 5 to 200 mi^2 catchment area) from June through September. We sampled all 13 sites, 11 headwater and 2 wadeable streams, during May. Like Pond et al. (2003), we collected the riffle sample with a kick seine, 0.25 m^2 sample square, and sieve bucket, and the multi-habitat sample with a D-frame net and sieve bucket (Appendix C).

The recommend sampling criteria for the developed MBI vary according to whether a stream is categorized as headwater or wadeable (Table 3). The 11 headwater sites had the macroinvertebrate samples collected in mid-May within the recommended February to May sample period for headwater categorized streams (Table 3; Pond et al. 2003). The two wadeable categorized streams also had the macroinvertebrate samples collected in mid-May, two weeks earlier than the recommended June to September sample period.

The MBI scores the sample sites and rates their biotic integrity as either Excellent (≥ 82 **Wadeable**, ≥ 83 **Headwater**), Good (75-81 W, 72-82 H), Fair (50-74 W, 48-71 H), Poor (25-49 W, 24-47 H), or Very-Poor (0-24 W, 0-23 H) (Pond et al. 2003). When an MBI score fell close (± 2 points) to the

classification threshold, we followed Compton et al.'s (2003) KIBI guideline that the rating contain both categories (i.e. Fair/Good) and Pond et al.'s (2003) recommendation that caution and any additional data (i.e. KIBI and stream habitat data) be used for a more thorough weight-of-evidence approach.

Stream Habitat Inventory

Two-person teams completed abbreviated stream habitat inventories (Roghair and Nuckols 2005) based on the basinwide visual estimation technique (BVET) (Dolloff et al. 1993). For each habitat unit contained entirely or partially within the sample site, the team visually estimated or measured the following attributes:

All Habitat Units	Sub-Sample of Habitat Units
Type of habitat	Bankfull channel width
Length and width	Channel gradient
Maximum and average depth	Water temperature
Riffle crest depth	Photographs
Dominant and subdominant substrate	GPS coordinates
Rosgen channel type (Rosgen, 1996)	
Percent fines	
Large wood counts	

When possible, the team sub-sampled at least 3 fast water and 3 slow water units within each sample site. During data analysis the following attributes were averaged for the site as a whole; maximum depth, average depth, pool residual depth, wetted width, bankfull channel with, percent fines, gradient, and water temperature (Table 4). In addition, the team noted stream features, including:

- Waterfalls
- Tributaries
- Side channels
- Braided channels
- Seeps (springs)
- Landslides
- Bridges
- Fords
- Dams
- Culverts

See Appendix A and B for detailed field methods. Of the 96 EPA sites, two sites had no fast water units present (i.e. riffle, run, or cascade).

Pebble Count Inventory

Fish sampling teams conducted pebble counts (Wolman heel-to-toe steps protocol; Wolman, 1954) in riffle habitat units to characterize the substrate at sample sites. Team members measured the intermediate axis of a minimum of 200 pebbles per riffle as described in Bunte and Abt (2001) and Kappesser (2002). In addition to pebble counts, depositional bar counts were conducted by measuring the

intermediate axis of 30 dominant large particles residing on a bar or similar depositional feature within the sample site (three of the 96 EPA sites did not contain a depositional bar). See Appendix A and D for detailed field methods.

Results

Fish and Macroinvertebrate Inventories, KIBI, and MBI

We collected a total of 26 fish species among the 13 sites; at a single site we found as many as 20 (Elk Creek) and as few as 1 species (Sugar Creek) (Table 5). The most prevalent species were Creek Chub (present at all sites), Fantail Darter (present at 12 sites), and Central Stoneroller (present at 10 sites) (Table 5). Creek Chub were the most numerous species while all other species were found in relatively low numbers. Some species were only found at a single site (Golden Redhorse, Bluegill, Telescope Shiner, Western Blacknose Dace, Stonecat, Kentucky Arrow Darter, and Variegated Darter) (Table 5). The median number of species per site was seven, as compared to 12 species per site for EPA sites, which is less than the 25th percentile (9 species) at the EPA sites. (Figure 5).

The KIBI rated 2 sites as Poor, 6 as Fair, 3 as Good, 1 as Good/Excellent, and 1 as Excellent (Table 6, Figure 6). The MBI rated 2 sites as Fair, 3 as Fair/Good, 2 as Good, 3 as Good/Excellent, and 3 as Excellent (Table 7, Figure 6).

The ratings provided by the KIBI and the MBI were not always similar for a site. Nine sites had a KIBI rating that was ½ to 3 ratings worse than the MBI, 2 sites had an MBI rating 1½ to 2 ratings worse than the KIBI, and 2 sites had an equal rating for both the KIBI and MBI (Figure 6).

Habitat Inventory

Sample sites had mean pool depths ranging from 20 to 50 cm, average bankfull channel widths from 4.8 to 12.8 m, channel gradient from 1 – 2%, and were classified as Rosgen channel types B, C, and F (Table 4). Three sites had >35% average percent fines in pools; Henry Fork, Bear Branch, and Elk Creek (Table 4). The median percent fines in pools and riffles were within the 25th – 75th percentile range of the EPA sites (Figure 7).

All sites had a greater percentage of riffle than pool habitat, with the exception of Bear Creek site DBF04052740, which had 53% pool and 47% riffle area (Table 8). The mine sites had less pool and more riffle area than the EPA sites; falling outside the EPA site's 25th – 75th percentile (Figure 8).

Total large wood per kilometer (LW/km) ranged from 0 to 51 pieces (Table 9). The median amount of LW/km at the mine influenced sites (12 pieces/km) was less than the 25th percentile (14 pieces/km) at the EPA sites (Figure 9).

We encountered a variety of substrates, including sand, small gravel, large gravel, cobble, boulder, and bedrock (Table 10). Bedrock most frequently occurred in pools, and boulder and cobble were most common in riffles (Figures 10 and 11). Substrate was skewed towards coarser materials as compared to the EPA sites (Figures 10 and 11).

Pebble Count Inventory

Riffle stability index (RSI) values ranged from 27.3 to 87.9 among the 13 sites (Table 11). The median RSI value (75.1) was within the 25th – 75th percentile at the EPA sites (Figure 12).

Discussion

Only 3 of the 13 sites we sampled on the Redbird District were rated as Good or better by both the KIBI and MBI. The KIBI and MBI are formulated based on reference conditions and because all regions of Kentucky have been disturbed by humans, reference sites fall under the classification of least disturbed rather than undisturbed. Several streams on the DBNF served as reference sites during the KIBI and MBI development because they are located on heavily forested and relatively undisturbed areas (Compton et al. 2003, Pond et al. 2003). A low KIBI or MBI rating suggests that past or present day disturbances are responsible for low biological integrity. In the streams we sampled on the Redbird District the most likely perpetrators include poor water quality and degraded stream habitat. The low habitat diversity and low amounts of large wood we found could in part explain the low biological integrity in some streams. Water quality information is being collected from these streams as part of a larger monitoring effort (Marguerite Wilson, DBNF Remedial Project Manager, pers. comm.) and may help to explain our results further.

The KIBI and MBI ratings deviated widely from each other for several streams. Most notably, two streams were rated as Poor by the KIBI, but were rated as Good or Excellent by the MBI. Although the KIBI and MBI both rate biotic integrity, they use different biota to do so. Macroinvertebrates (MBI) are relatively short-lived, have a wide range of tolerance levels, and have the ability to colonize streams relatively quickly because they can fly. These traits make them particularly responsive to changes in local stream quality; they respond quickly to disturbances and can recolonize a disturbed reach rapidly if conditions improve. Conversely, fish (KIBI) are longer lived and may be slower to recolonize previously disturbed reaches, particularly where physical, temperature, or chemical barriers still persist downstream of previously disturbed reaches. Previous studies have suggested that macroinvertebrate ratings are more closely correlated to local conditions, whereas fish are more closely correlated to larger scale conditions (Freund and Petty 2007). Apparent discrepancies in the KIBI and MBI ratings reflect the differences in

the type and scale of disturbance, time since last disturbance, the presence of barriers to recolonization, and the inherent colonization potential of indicator organisms.

Several of the sites we sampled had small upstream catchment areas. In small headwater streams the KIBI rating can vary widely with small changes in the number or type of fish collected. For example, the total number of fish sampled in Spencer Branch (1.2 mi² catchment area) was 48 adult individuals (47 Creek Chubs and 1 Fantail Darter), resulting in a score of 27, which is a Poor KIBI rating (Poor: 19 to 38). If only two additional fish were caught (50 individuals) it would have changed the score to 49, which is a Fair rating (Fair: 39 to 58). To score as Very-Poor would have required no fish captured. Any stream in a small watershed where 50 fish (even if all are the same species) are captured will result in at least a Fair rating, so it should be understood that a site being rated Very-Poor, Poor, versus Fair may have limited meaning and it may be more relevant to think of a site as being rated either '< Good' or '≥ Good'. It will be challenging for a site with a small catchment area to rate as Excellent because it would require a fish community that is both diverse and abundant. Given these distinctions to the scoring, it is important that the development of management and/or remediation plans consider the reasons why a site was scored and rated as it was rather than simply accepting the qualitative rating.

Streams on the Redbird District reflect the challenges facing many national forests with mixed ownership and mineral rights as well as the lingering legacy influence of past land use. The DBNF is generally more forested and less disturbed than other areas of Kentucky, but conditions on the Redbird District warrant continued monitoring to determine the trajectory of stream quality in the area and to identify opportunities for remediation to improve water quality and stream habitat.

Data Availability

Summer 2015 stream habitat, fish, and pebble count data reside in a MS Access database, which is managed by the CATT, and a copy has been provided to Jon Walker, DBNF Forest Hydrologist. We will work with the DBNF to develop custom queries and reports for the MS Access database, as needed.

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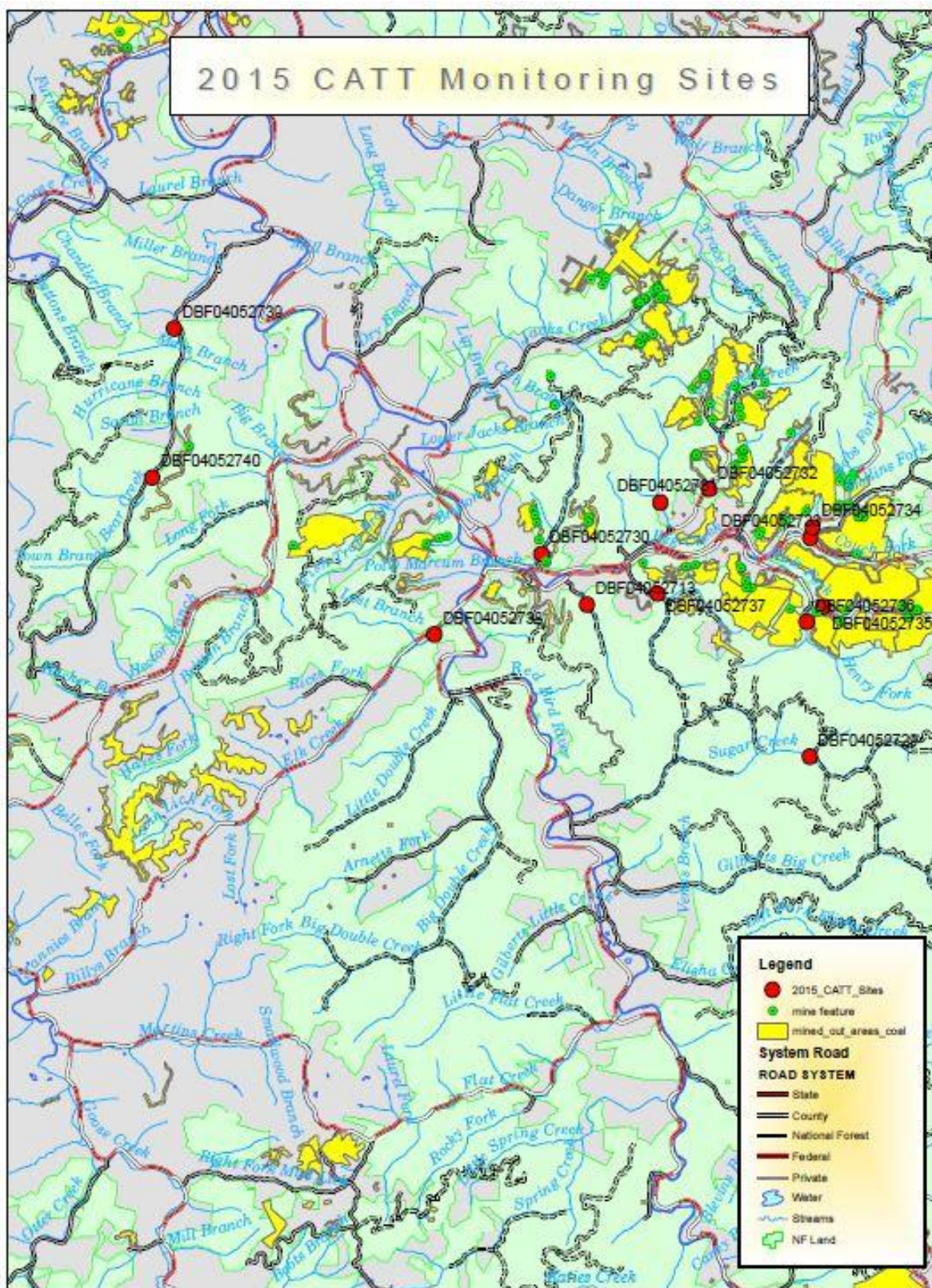


Figure 1. 2015 sample sites (red dots), mine features (green dots), and mined out areas (yellow areas) on the Redbird Ranger District, Daniel Boone National Forest, Kentucky.

ROOM AND PILLAR MINING

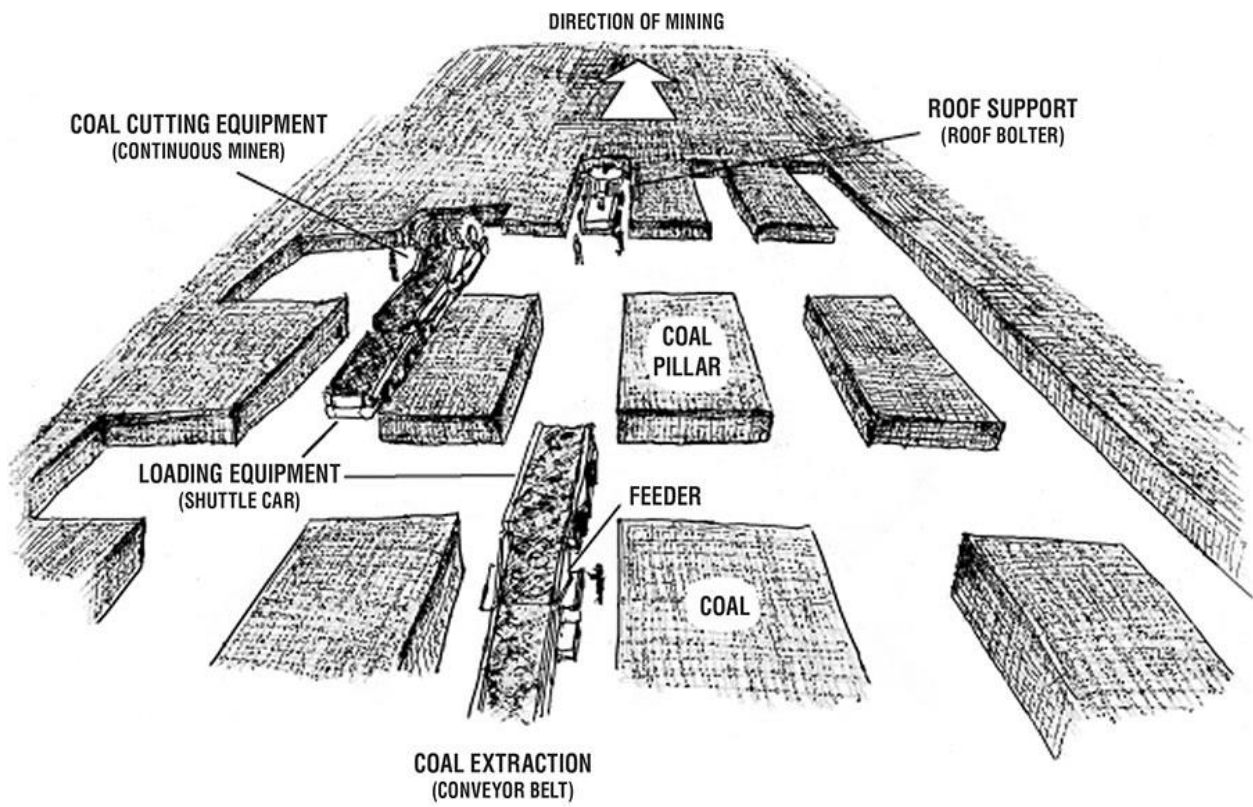


Figure 2. Example of an underground mine using the room-and-pillar mining method.

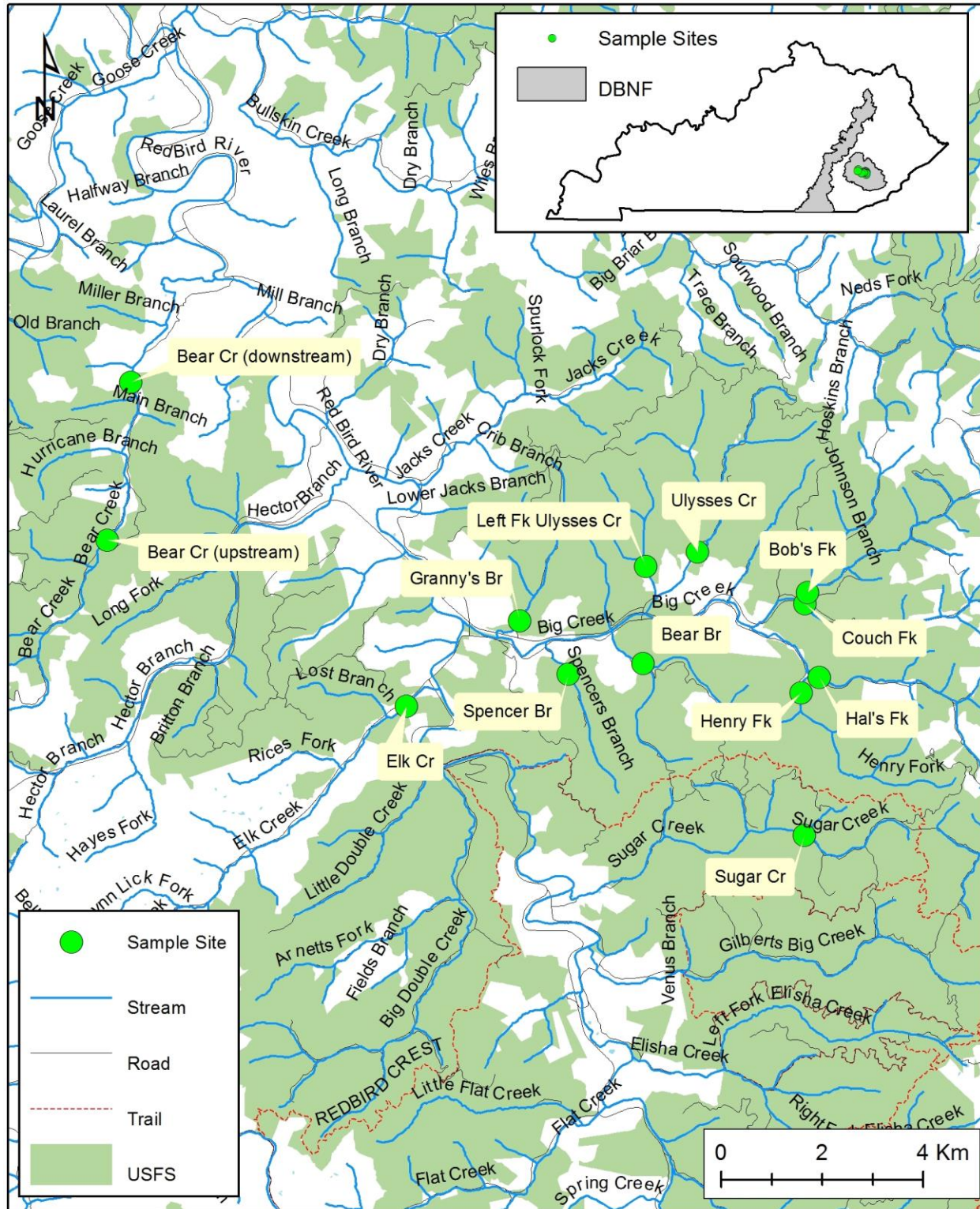


Figure 3. Sample site locations, Redbird District, Daniel Boone National Forest, Kentucky.

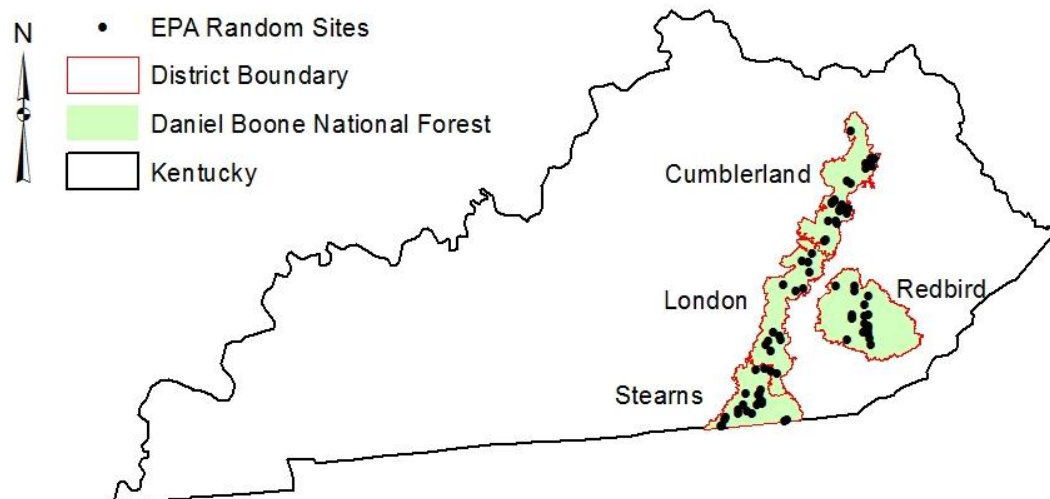


Figure 4. Environmental Protection Agency (EPA) randomly selected site locations sampled by the CATT from 2005 to 2013 (n=96). Sample site locations are within the Cumberland, London, Redbird, and Stearns Districts, Daniel Boone National Forest, Kentucky.

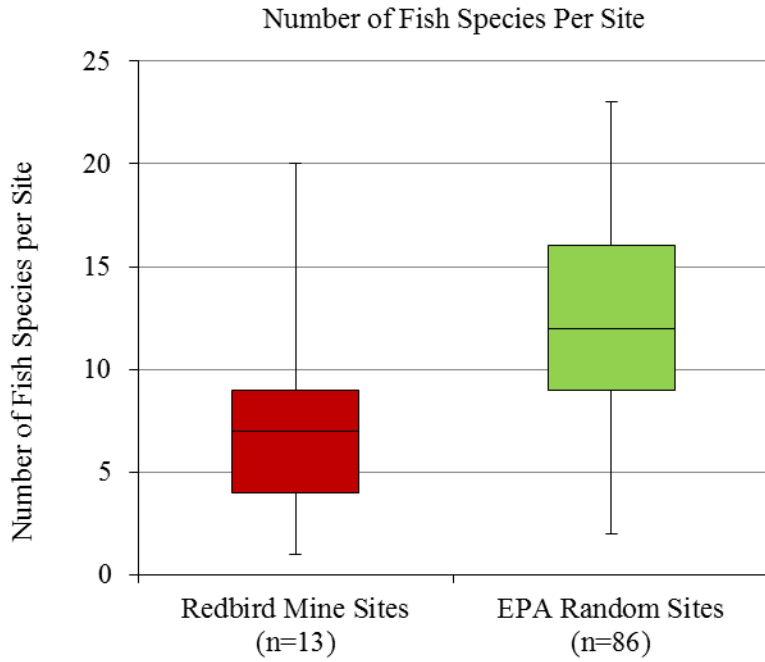


Figure 5. Boxplot of number of fish species at sample sites on the Redbird District and EPA randomly selected sites located throughout the DBNF.

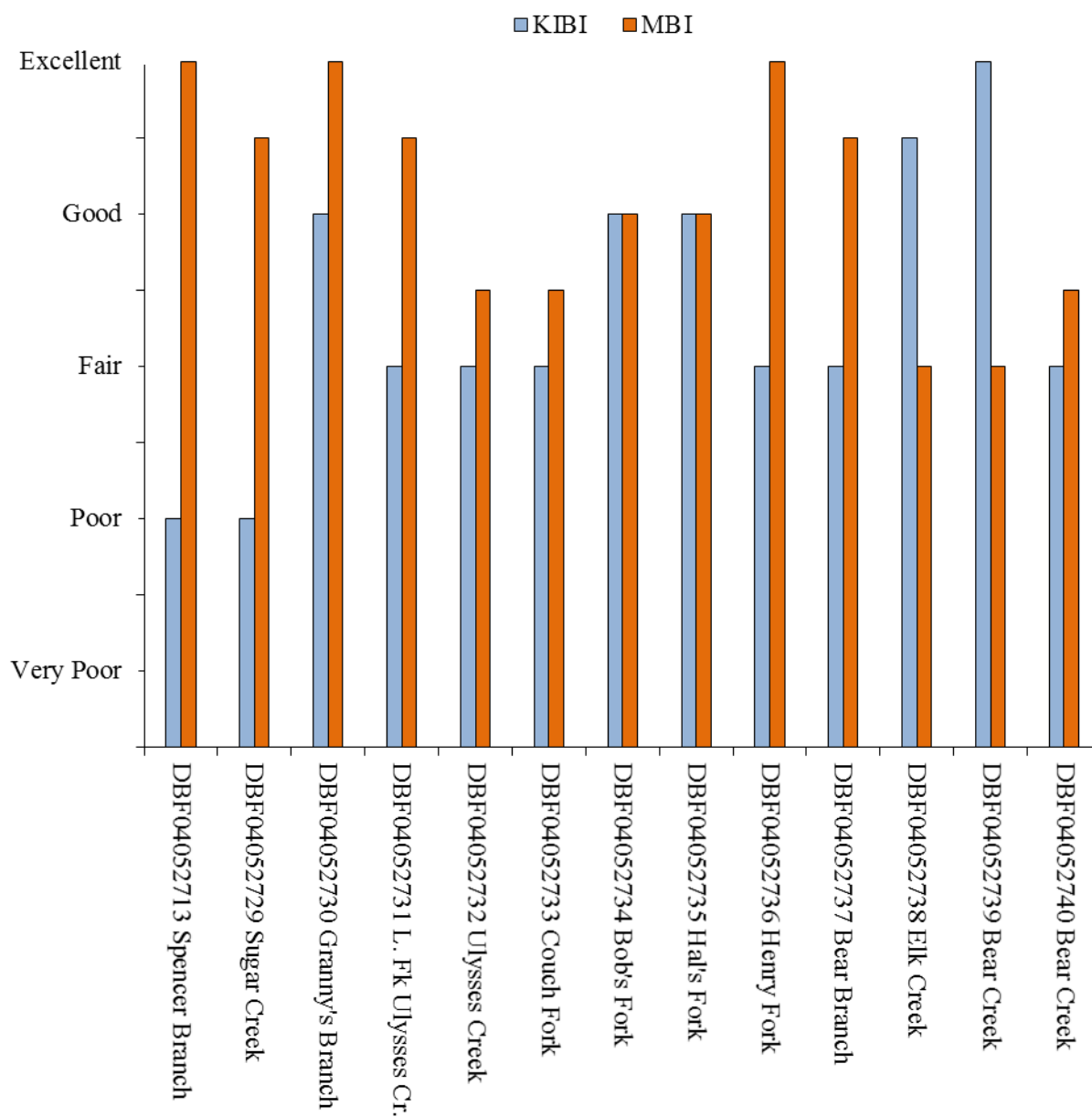


Figure 6. Kentucky index of biotic integrity (KIBI) and macroinvertebrate bioassessment index (MBI) rating results for sites on Redbird District, May and July 2015.

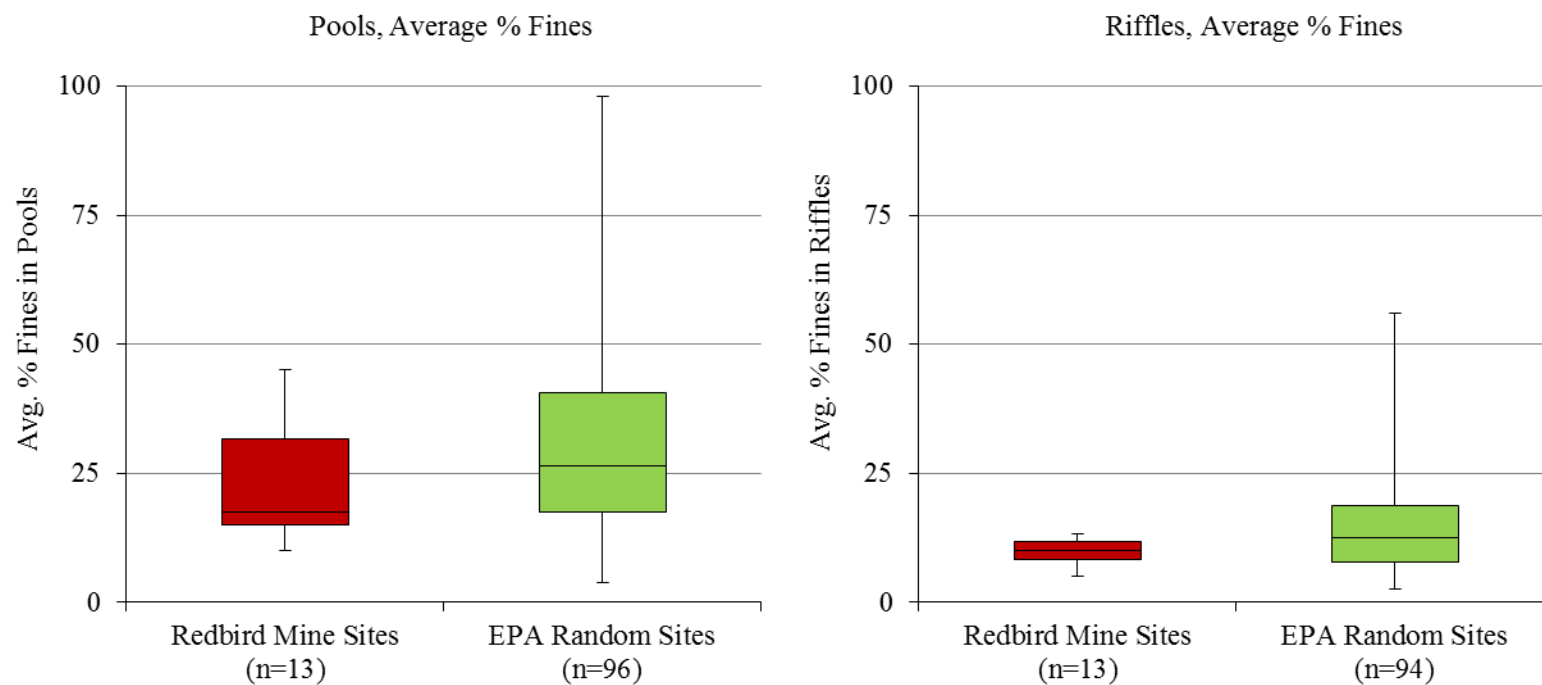


Figure 7. Boxplots of average percent fines (i.e. surface area of the stream bed consisting of sand, silt, or clay) in pools and riffles at sample sites on the Redbird District and EPA randomly selected sites located throughout the DBNF (two of the 96 EPA sites contained no fast water units).

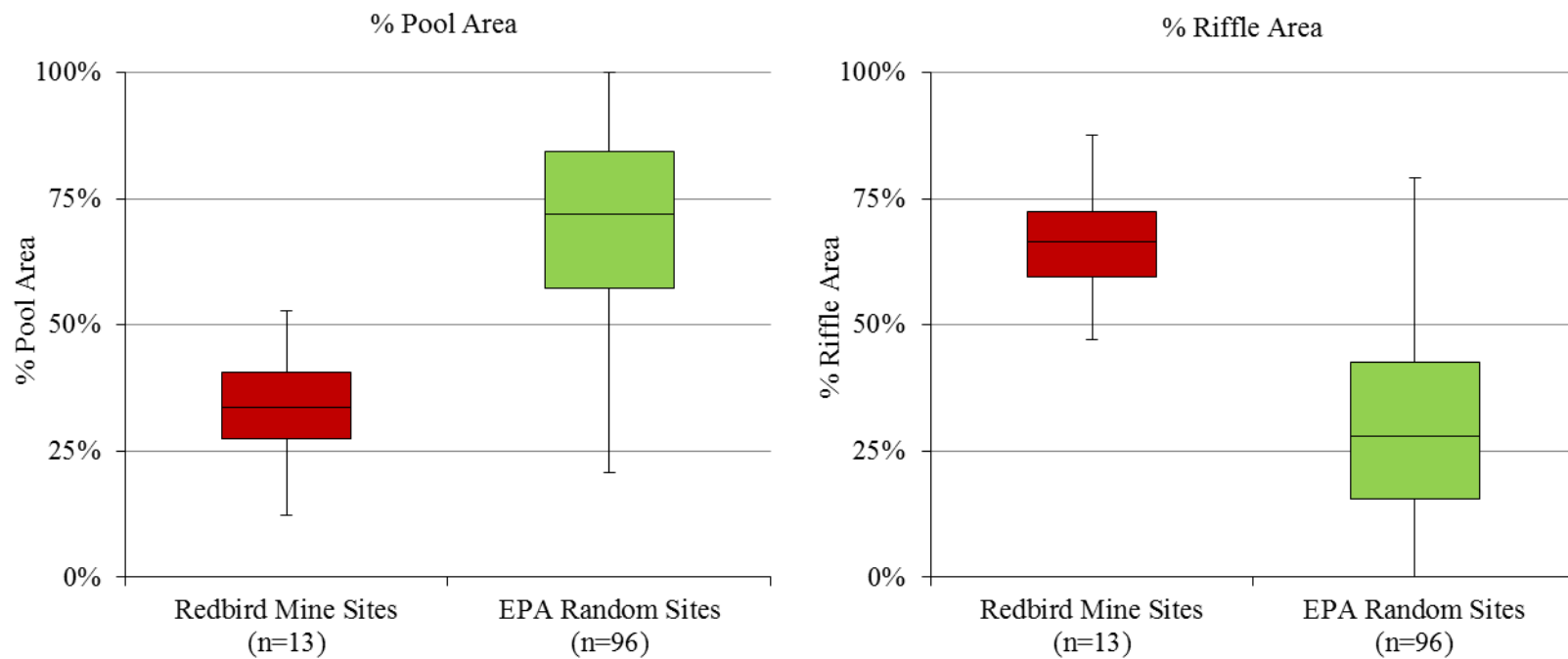


Figure 8. Boxplots of percent pool and riffle area at sample sites on the Redbird District and EPA randomly selected sites located throughout the DBNF.

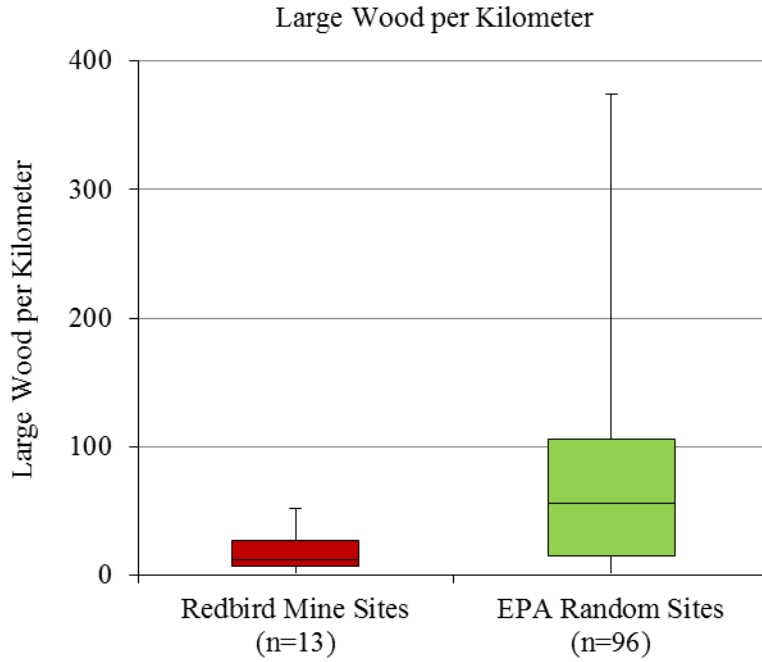


Figure 9. Boxplot of total large wood per kilometer (size classes 1, 2, 3, and 4; see Appendix B for size classes) at sample sites on the Redbird District and EPA randomly selected sites located throughout the DBNF.

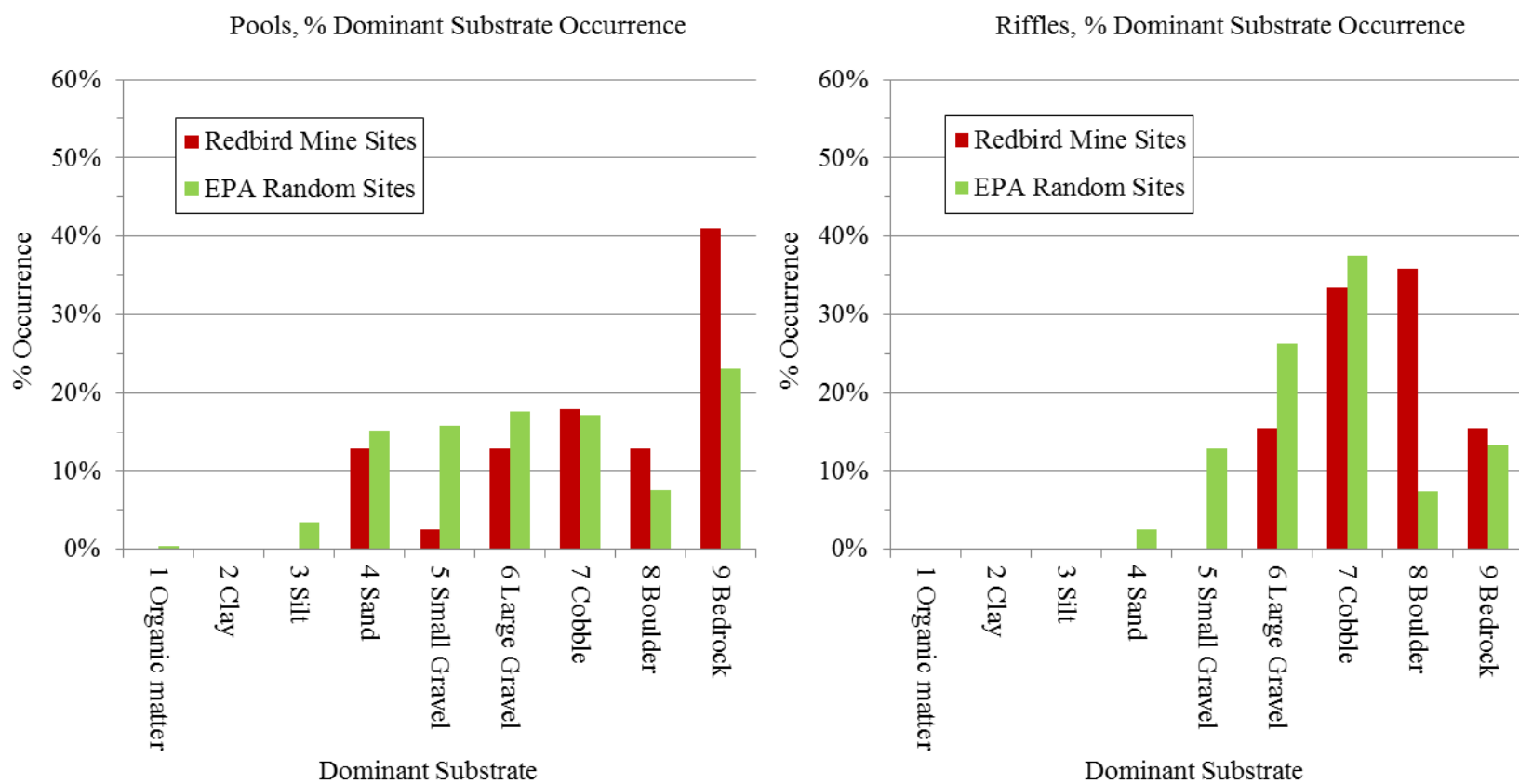


Figure 10. Percent occurrence of dominant substrate size categories in pools and riffles at sample sites on the Redbird District (n=13) and EPA randomly selected sites (n=96) located throughout the DBNF.

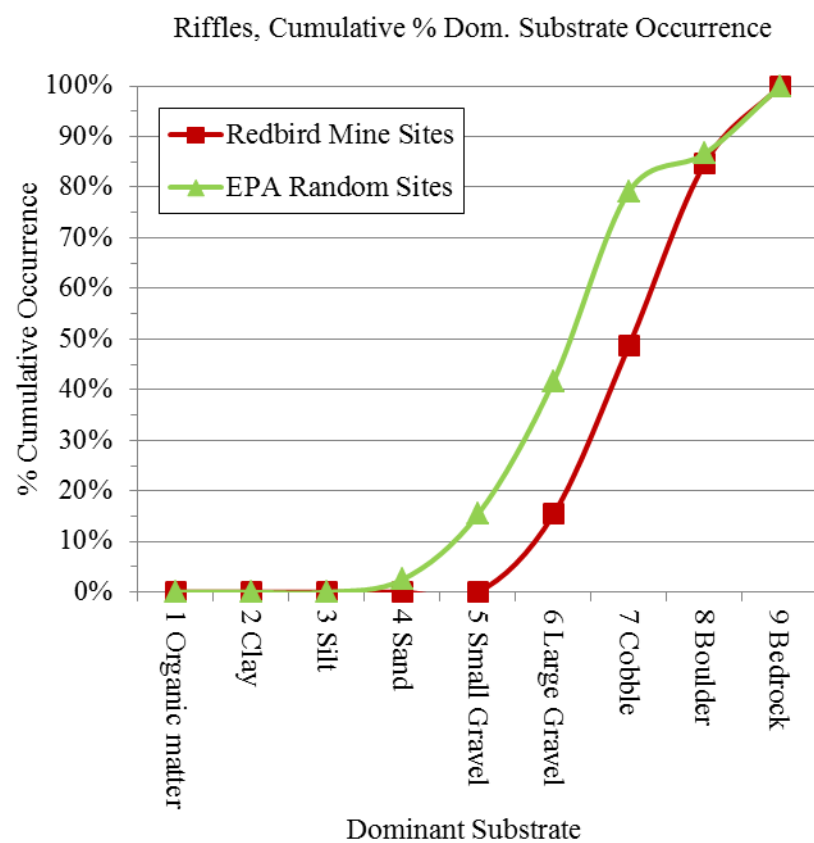
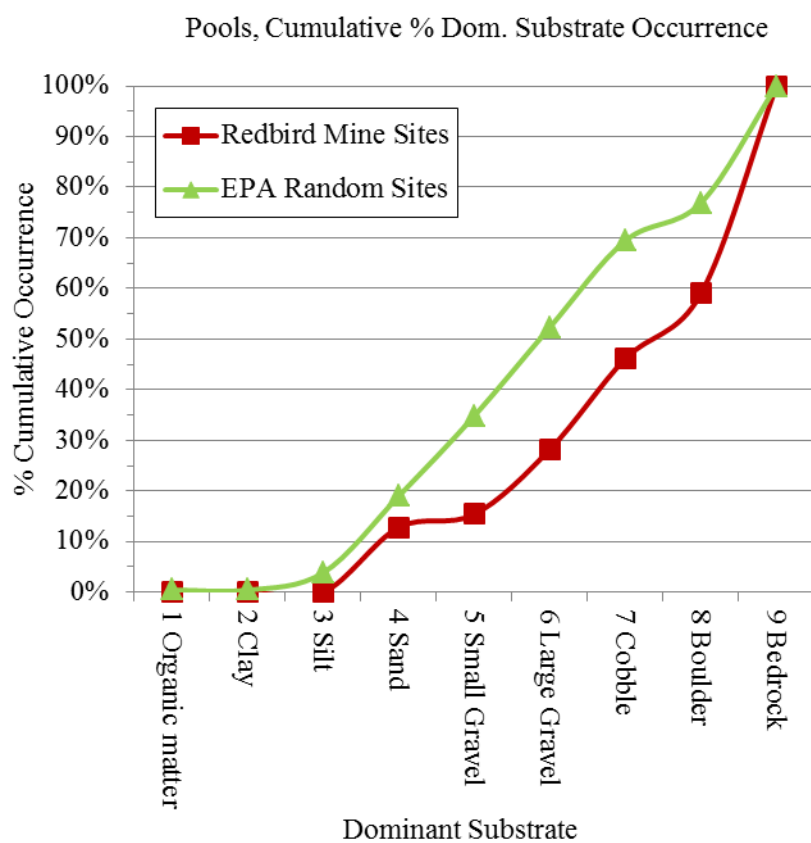


Figure 11. Cumulative percent occurrence of dominant substrate size categories in pools(left graph) and riffles (right graph) at sample sites on the Redbird District (n=13) and EPA randomly selected sites (n=96) located throughout the DBNF.

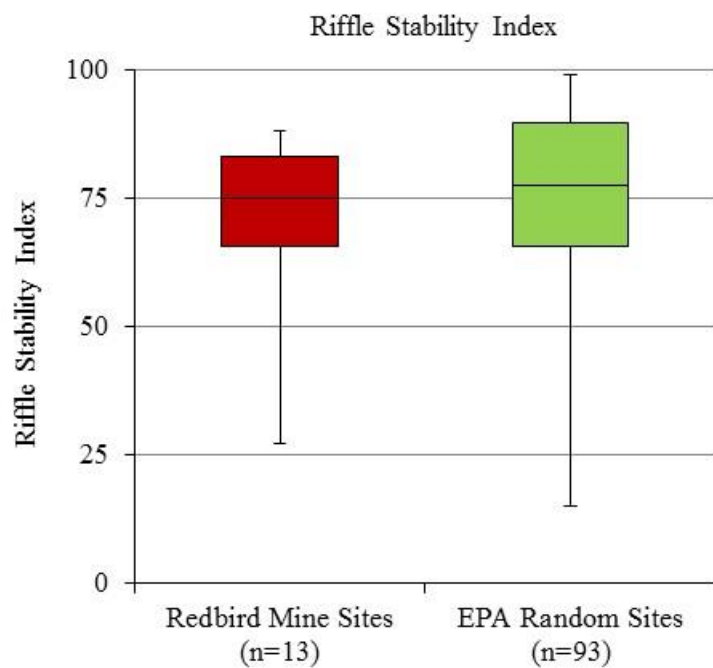


Figure 12. Boxplot of riffle stability index (RSI) values at sample sites on the Redbird District and EPA randomly selected sites located throughout the DBNF (three of the 96 EPA sites did not contain a depositional bar).

Table 1. Data collected at sites on the Redbird District. Data were collected in May (macroinvertebrates) and July (BVET & Efish) 2015.

Site #	Stream Name	Topo Quad	Macro-inverts	BVET habitat (m)	Efish (sec)	Comments
DBF04052713	Spencer Branch	Big Creek	collected	155	1,053	crayfish observed
DBF04052729	Sugar Creek	Big Creek	collected	154	562	crayfish observed
DBF04052730	Granny's Branch	Big Creek	collected	164	719	crayfish observed
DBF04052731	Left Fork Ulysses Creek	Big Creek	collected	141	462	crayfish observed
DBF04052732	Ulysses Creek	Big Creek	collected	225	922	crayfish observed
DBF04052733	Couch Fork	Big Creek	collected	138	770	crayfish observed
DBF04052734	Bob's Fork	Big Creek	collected	188	1,151	crayfish observed
DBF04052735	Hal's Fork	Big Creek	collected	201	749	crayfish observed
DBF04052736	Henry Fork	Big Creek	collected	176	963	crayfish observed
DBF04052737	Bear Branch	Big Creek	collected	160	797	crayfish observed; gasoline/sulphur smell
DBF04052738	Elk Creek	Big Creek	collected	340	1,475	crayfish observed
DBF04052739	Bear Creek (downstream)	Barcreek	collected	267	2,181	crayfish observed
DBF04052740	Bear Creek (upstream)	Barcreek	collected	215	1,118	crayfish observed
			Total	2,524		

Table 2. GPS coordinates recorded at the downstream (start) and upstream (end) extent of stream habitat and fish inventories on the Redbird District, July 2015.

Site #	Stream Name	GPS (UTM NAD83)	
		Downstream Inventory Start	Upstream Inventory End
DBF04052713	Spencer Branch	17 S 272707 4115465	17 S 272720 4115337
DBF04052729	Sugar Creek	17 S 277240 4111883	17 S 277371 4111846
DBF04052730	Granny's Branch	17 S 271813 4116417	17 S 271878 4116549
DBF04052731	Left Fork Ulysses Creek	17 S 274375 4117414	17 S 274369 4117510
DBF04052732	Ulysses Creek	17 S 275472 4117639	17 S 275646 4117765
DBF04052733	Couch Fork	17 S 277424 4116522	17 S 277522 4116434
DBF04052734	Bob's Fork	17 S 277633 4116708	17 S 277702 4116812
DBF04052735	Hal's Fork	17 S 277732 4114982	17 S 277887 4114874
DBF04052736	Henry Fork	17 S 277326 4114668	17 S 277291 4114518
DBF04052737	Bear Branch	17 S 274277 4115440	17 S 274377 4115333
DBF04052738	Elk Creek	17 S 269666 4114995	17 S 269453 4114817
DBF04052739	Bear Creek	17 S 264495 4121262	17 S 264524 4120998
DBF04052740	Bear Creek	17 S 263749 4118464	17 S 263680 4118317

Table 3. Kentucky index of biotic integrity (KIBI) and macroinvertebrate bioassessment index (MBI) sampling criteria. Sites on the Redbird District are located within the Southwestern Appalachian ecoregion, the Upper Cumberland major river basin, and the Mountain ichthyoregion/bioregion. Some sites were not sampled within the KIBI and MBI recommended criteria for sampling month, site length, and electrofishing duration.

Site #	Stream Name	Catchment Area (mi ²)	KIBI ¹	MBI ²	Sampling Month ³		Electrofishing	
			Headwater/Wadeable		KIBI	MBI	Reach Length ⁴ (m)	Duration ⁵ (sec)
DBF04052713	Spencer Branch	1.4	Headwater	Headwater	July	May	152	1,053
DBF04052729	Sugar Creek	1.9	Headwater	Headwater	July	May	148	562
DBF04052730	Granny's Branch	1.4	Headwater	Headwater	July	May	160	719
DBF04052731	Left Fork Ulysses Creek	1.3	Headwater	Headwater	July	May	120	462
DBF04052732	Ulysses Creek	3.3	Headwater	Headwater	July	May	224	922
DBF04052733	Couch Fork	2.2	Headwater	Headwater	July	May	135	770
DBF04052734	Bob's Fork	4.5	Headwater	Headwater	July	May	175	1,151
DBF04052735	Hal's Fork	2.4	Headwater	Headwater	July	May	201	749
DBF04052736	Henry Fork	2.7	Headwater	Headwater	July	May	176	963
DBF04052737	Bear Branch	2.1	Headwater	Headwater	July	May	160	797
DBF04052738	Elk Creek	8.3	Wadeable	Wadeable	July	May	300	1,475
DBF04052739	Bear Creek	6.4	Wadeable	Wadeable	July	May	256	2,181
DBF04052740	Bear Creek	3.4	Headwater	Headwater	July	May	211	1,118

1. KIBI headwater streams = <6 mi² catchment area, wadeable streams = >10 mi², and the gray area of 6-10 mi² requires best professional judgment (Compton et al. 2003).
2. MBI headwater streams = <5 mi² catchment area and wadeable streams = 5-200 mi² (Pond et al. 2003).
3. KIBI sampling should occur mid-March through October (Compton et al. 2003). MBI sampling should occur February-May for headwater streams and June-September for wadeable streams (Pond et al. 2003).
4. KIBI sample site length should be 100-125 m for headwater streams and 100-200 m for wadeable streams (KDOW 2002). MBI sample site length is generally 100 m (Pond et al. 2003).
5. KIBI electrofishing duration should be 600-1,000 sec for headwater streams and 600-1,800 sec for wadeable streams (KDOW 2002).

Table 4. Summary of BVET stream habitat attributes collected on the Redbird District, July 2015.

Site #	Stream Name	Mean Avg. Depth (cm)		Mean Max. Depth (cm)		Mean Pool Residual Depth (cm)*	Avg. Wetted Width (m)		Avg. Bankfull Channel Width (m)	Avg. % Fines		Avg. Gradient (%)	Avg. Water Temp. (C)	Rosen
		Pools	Riffles	Pools	Riffles		Pools	Riffles		Pools	Riffles			
DBF04052713	Spencer Branch	27	12	38	35	0	3.7	3.3	4.8	17	8	2	19	F
DBF04052729	Sugar Creek	35	27	58	50	5	3.5	4.0	6.5	32	8	2	17	C,F
DBF04052730	Granny's Branch	30	13	55	35	3	4.3	3.3	5.3	18	13	2	20	F
DBF04052731	L. Fk. Ulysses Cr.	26	15	43	25	NA	3.1	3.2	6.8	15	7	1	20	B,F
DBF04052732	Ulysses Creek	26	8	43	19	0	8.6	8.4	12.8	13	5	1	18	C,F
DBF04052733	Couch Fork	20	11	35	28	5	4.0	3.5	5.6	18	8	1	20	F
DBF04052734	Bob's Fork	46	17	69	53	22	4.3	7.0	9.4	29	13	1	18	C,F
DBF04052735	Hal's Fork	38	25	69	54	11	4.6	4.7	6.3	28	10	2	18	F
DBF04052736	Henry Fork	50	35	90	65	25	5.0	3.8	6.8	40	10	1	18	F
DBF04052737	Bear Branch	25	13	38	28	NA	5.0	4.4	5.7	45	13	1	20	F
DBF04052738	Elk Creek	30	17	63	50	0	8.7	8.5	12.4	37	12	1	24	F
DBF04052739	Bear Creek	43	13	50	18	3	7.4	7.2	9.6	10	10	2	21	F
DBF04052740	Bear Creek	28	15	40	21	6	6.1	3.7	8.6	11	10	1	21	F

*Residual pool depth = average pool depth – riffle crest depth

Table 5. Total count (adult & age-0) of fish captured at each sample site, Redbird District, July 2015.

Scientific Name	Common Name	DBF04052713 Spencer Branch	DBF04052729 Sugar Creek	DBF04052730 Granny's Branch	DBF04052731 L. Fk Ulysses Cr.	DBF04052732 Ulysses Creek	DBF04052733 Couch Fork	DBF04052734 Bob's Fork
<u>Catostomidae</u>								
<i>Catostomus commersoni</i>	White Sucker	0	0	0	0	0	0	5
<i>Hypentelium nigricans</i>	N. Hog Sucker	0	0	0	0	10	5	15
<i>Moxostoma erythrurum</i>	Golden Redhorse	0	0	0	0	0	0	2
<u>Centrarchidae</u>								
<i>Ambloplites rupestris</i>	Rock Bass	0	0	0	0	0	0	2
<i>Lepomis cyanellus</i>	Green Sunfish	0	0	16	0	0	0	0
<i>Lepomis macrochirus</i>	Bluegill	0	0	0	0	0	0	0
<i>Lepomis megalotis</i>	Longear Sunfish	0	0	0	0	0	0	2
<i>Micropterus dolomieu</i>	Smallmouth Bass	0	0	0	0	1	0	9
<u>Cyprinidae</u>								
<i>Camptostoma anomalum</i>	Central Stoneroller	0	0	2	0	51	75	48
<i>Chrosomus erythrogaster</i>	S. Redbelly Dace	0	0	6	5	0	8	0
<i>Luxilus chrysocephalus</i>	Striped Shiner	0	0	0	0	2	28	18
<i>Lythrurus fasciolaris</i>	Scarlet Shiner	0	0	0	0	0	0	14
<i>Notropis buccatus</i>	Silverjaw Minnow	0	0	0	0	0	1	0
<i>Notropis photogenis</i>	Silver Shiner	0	0	0	0	0	0	6
<i>Notropis telescopus</i>	Telescope Shiner	0	0	0	0	0	0	0
<i>Pimephales notatus</i>	Bluntnose Minnow	0	0	0	0	0	0	4
<i>Rhinichthys obtusus</i>	W. Blacknose Dace	0	0	0	0	0	0	0
<i>Semotilus atromaculatus</i>	Creek Chub	48	41	43	124	198	64	41
<u>Ictaluridae</u>								
<i>Noturus flavus</i>	Stonecat	0	0	0	0	0	0	0
<u>Percidae</u>								
<i>Etheostoma blennioides</i>	Greenside Darter	0	0	0	0	0	1	0
<i>Etheostoma caeruleum</i>	Rainbow Darter	0	0	3	0	3	9	8
<i>Etheostoma flabellare</i>	Fantail Darter	1	0	3	1	7	8	14
<i>Etheostoma nigrum</i>	Johnny Darter	0	0	0	0	0	0	0
<i>Etheostoma sagitta spilotum</i>	KY Arrow Darter	0	0	0	0	0	0	0
<i>Etheostoma variatum</i>	Variegated Darter	0	0	0	0	0	0	1
<i>Percina stictogaster</i>	Frecklebelly Darter	0	0	2	0	0	0	2

Table 5 continued.

Scientific Name	Common Name	DBF04052735 Hal's Fork	DBF04052736 Henry Fork	DBF04052737 Bear Branch	DBF04052738 Elk Creek	DBF04052739 Bear Creek	DBF04052740 Bear Creek
<u>Catostomidae</u>							
<i>Catostomus commersoni</i>	White Sucker	0	0	0	1	2	1
<i>Hypentelium nigricans</i>	N. Hog Sucker	5	0	0	15	6	1
<i>Moxostoma erythrurum</i>	Golden Redhorse	0	0	0	0	0	0
<u>Centrarchidae</u>							
<i>Ambloplites rupestris</i>	Rock Bass	0	0	0	2	1	0
<i>Lepomis cyanellus</i>	Green Sunfish	0	0	0	2	0	0
<i>Lepomis macrochirus</i>	Bluegill	0	0	0	1	0	0
<i>Lepomis megalotis</i>	Longear Sunfish	0	0	0	3	0	0
<i>Micropterus dolomieu</i>	Smallmouth Bass	0	0	0	3	0	0
<u>Cyprinidae</u>							
<i>Camptostoma anomalum</i>	Central Stoneroller	33	2	14	60	107	3
<i>Chrosomus erythrogaster</i>	S. Redbelly Dace	6	8	1	0	25	30
<i>Luxilus chrysocephalus</i>	Striped Shiner	1	0	0	31	1	1
<i>Lythrurus fasciolaris</i>	Scarlet Shiner	0	0	0	2	0	0
<i>Notropis buccatus</i>	Silverjaw Minnow	0	0	0	2	3	0
<i>Notropis photogenis</i>	Silver Shiner	1	0	0	1	0	0
<i>Notropis telescopus</i>	Telescope Shiner	0	0	0	0	1	0
<i>Pimephales notatus</i>	Bluntnose Minnow	0	0	0	18	1	0
<i>Rhinichthys obtusus</i>	W. Blacknose Dace	0	0	0	3	0	0
<i>Semotilus atromaculatus</i>	Creek Chub	95	44	60	37	81	137
<u>Ictaluridae</u>							
<i>Noturus flavus</i>	Stonecat	0	0	0	0	1	0
<u>Percidae</u>							
<i>Etheostoma blennioides</i>	Greenside Darter	1	0	0	8	1	0
<i>Etheostoma caeruleum</i>	Rainbow Darter	4	0	0	13	12	0
<i>Etheostoma flabellare</i>	Fantail Darter	2	4	7	12	26	3
<i>Etheostoma nigrum</i>	Johnny Darter	0	0	0	4	2	0
<i>Etheostoma sagitta spilotum</i>	KY Arrow Darter	0	0	0	0	7	0
<i>Etheostoma variatum</i>	Variegate Darter	0	0	0	0	0	0
<i>Percina stictogaster</i>	Frecklebelly Darter	0	0	0	7	6	0

Table 6. Kentucky index of biotic integrity (KIBI) results for each sample site, Redbird District, July 2015.

		DBF04052713 Spencer Branch	DBF04052729 Sugar Creek	DBF04052730 Granny's Branch	DBF04052731 L. Fk Ulysses Cr.	DBF04052732 Ulysses Creek	DBF04052733 Couch Fork	DBF04052734 Bob's Fork	DBF04052735 Hal's Fork	DBF04052736 Henry Fork	DBF04052737 Bear Branch	DBF04052738 Elk Creek	DBF04052739 Bear Creek	DBF04052740 Bear Creek
Raw Metric Values	TNI	48	41	60	129	266	188	185	148	51	82	220	257	166
	NAT	2	1	7	3	7	9	16	9	4	4	20	17	7
	DMS	1	--	3	1	2	3	4	3	1	1	5	7	1
	INT	--	--	2	1	--	1	3	2	1	1	2	5	1
	SL	--	--	3	1	3	5	8	6	1	1	8	7	4
	%INSCT	2	--	13	1	7	12	34	9	8	9	29	24	2
	%TOL	98	100	73	95	73	44	36	65	73	73	42	24	78
	%FHW	--	--	5	--	20	56	56	24	4	17	63	45	2
Calc. Metric Scores	NAT	61	50	77	64	63	77	90	75	56	60	95	88	63
	DMS	59	42	78	58	55	72	73	71	48	51	75	100	44
	INT	52	45	76	64	37	56	71	68	53	57	49	92	50
	SL	53	46	75	60	62	84	97	91	49	53	88	84	69
	%INSCT	0	0	50	43	32	45	57	39	36	42	43	41	26
	%TOL	0	0	50	37	47	81	81	59	50	50	69	89	43
	%FHW	0	0	50	56	60	0	12	41	50	48	20	41	90
	KIBI headwater	27	22	63	53	49	56	65	61	48	50	--	--	54
	KIBI wadeable	--	--	--	--	--	--	--	--	--	--	70	82	--
	Rating	Poor	Poor	Good	Fair	Fair	Fair	Good	Good	Fair	Fair	Good/ Excellent	Excellent	Fair

TNI = total number individuals; NAT = native species richness; DMS = darter, madtom, and sculpin richness; INT = intolerant species richness; SL = simple lithophilic spawning species richness; %INSCT = relative abundance of insectivorous individuals; %TOL = relative abundance of tolerant individuals; %FHW = relative abundance of facultative headwater individuals

KIBI ratings: Excellent ≥ 71 ; Good 59-70; Fair 39-58; Poor 19-38; Very-Poor 0-18

Table 7. Kentucky macroinvertebrate bioassessment index (MBI) results for each sample site, Redbird District, May 2015.

		DBF04052713 Spencer Branch	DBF04052729 Sugar Creek	DBF04052730 Granny's Branch	DBF04052731 L. Fk Ulysses Cr.	DBF04052732 Ulysses Creek	DBF04052733 Couch Fork	DBF04052734 Bob's Fork	DBF04052735 Hal's Fork	DBF04052736 Henry Fork	DBF04052737 Bear Branch	DBF04052738 Elk Creek	DBF04052739 Bear Creek	DBF04052740 Bear Creek
Raw Metric Values	TNI	448	362	250	116	194	96	104	385	230	232	442	144	171
	G-TR	43	43	41	30	40	26	31	41	44	40	29	47	30
	G-EPT	28	26	27	20	23	14	16	22	28	23	17	22	19
	mHBI	2	2	3	2	4	3	3	3	2	3	4	5	4
	m%EPT	81	81	85	77	46	74	73	84	82	75	38	56	70
	% Ephem	66	49	58	69	23	58	65	14	39	56	--	--	63
	% Chir+Olig	5	10	4	7	9	15	10	7	7	9	42	25	20
	% Clingers	83	62	71	66	80	68	62	74	86	70	73	43	49
Calc. Metric Scores	G-TR	68	68	65	48	63	41	49	65	70	63	39	64	48
	G-EPT	85	79	82	61	70	42	48	67	85	70	57	73	58
	mHBI	98	97	93	96	82	89	83	93	100	91	82	77	81
	m%EPT	93	93	98	88	53	85	84	97	95	87	52	76	80
	% Ephem	99	74	87	100	34	88	98	21	58	85	--	--	95
	% Chir+Olig	96	90	97	94	92	86	91	94	94	92	59	76	81
	% Clingers	100	83	94	88	100	90	82	98	100	93	99	58	65
MBI headwater		91	83	88	82	71	74	77	76	86	83	--	--	72
MBI wadeable		--	--	--	--	--	--	--	--	--	--	65	71	--
Rating		Excellent	Good/ Excellent	Excellent	Good/ Excellent	Fair/ Good	Fair/ Good	Good	Good	Excellent	Good/ Excellent	Fair	Fair	Fair/ Good

TNI = total number individuals; G-TR = genus taxa richness; G-EPT = genus ephemeroptera, plecoptera, trichoptera richness; mHBI = modified Hilsenhoff biotic index; M%EPT = modified percent EPT abundance; %Ephem = percent ephemeroptera; %Chir+Olig = percent chironomidae+oligochaeta; %Clingers = percent primary clingers

MBI headwater ratings: Excellent ≥ 83 ; Good 72-82; Fair 48-71; Poor 24-47; Very-Poor 0-23

MBI wadeable ratings: Excellent ≥ 82 ; Good 75-81; Fair 50-74; Poor 25-49; Very-Poor 0-24

Table 8. Stream area in pools (includes glides) and riffles (includes runs and cascades) observed during BVET habitat inventories at sample sites, Redbird District, July 2015.

Site #	Stream Name	Pool Area (m ²)	Riffle Area (m ²)	Total Area (m ²)	% Pool Area	% Riffle Area
DBF04052713	Spencer Branch	165	389	554	30%	70%
DBF04052729	Sugar Creek	124	397	520	24%	76%
DBF04052730	Granny's Branch	344	455	799	43%	57%
DBF04052731	Left Fork Ulysses Creek	187	274	461	41%	59%
DBF04052732	Ulysses Creek	894	995	1,890	47%	53%
DBF04052733	Couch Fork	87	419	505	17%	83%
DBF04052734	Bob's Fork	338	863	1,202	28%	72%
DBF04052735	Hal's Fork	257	678	935	28%	72%
DBF04052736	Henry Fork	85	604	689	12%	88%
DBF04052737	Bear Branch	172	340	512	34%	66%
DBF04052738	Elk Creek	959	1,671	2,630	36%	64%
DBF04052739	Bear Creek	1,026	1,561	2,587	40%	60%
DBF04052740	Bear Creek	482	430	912	53%	47%

Table 9. Large wood per kilometer observed during BVET habitat inventories at sample sites, Redbird District, July 2015 (see Appendix B for large wood size classes).

Site #	Stream Name	Large Wood per Km						Large Wood Count in Sample Reach						Inventory Distance (km)
		LW1/ km	LW2/ km	LW3/ km	LW4/ km	RW/ km	Total LW/km	LW1 n	LW2 n	LW3 n	LW4 n	RW n	Total LW n	
DBF04052713	Spencer Branch	6	0	0	0	0	6	1	0	0	0	0	1	0.16
DBF04052729	Sugar Creek	19	0	13	0	0	32	3	0	2	0	0	5	0.15
DBF04052730	Granny's Branch	0	0	0	0	0	0	0	0	0	0	0	0	0.16
DBF04052731	Left Fork Ulysses Creek	35	0	7	0	0	43	5	0	1	0	0	6	0.14
DBF04052732	Ulysses Creek	0	0	0	0	0	0	0	0	0	0	0	0	0.23
DBF04052733	Couch Fork	7	0	0	0	0	7	1	0	0	0	0	1	0.14
DBF04052734	Bob's Fork	16	0	5	0	5	27	3	0	1	0	1	5	0.19
DBF04052735	Hal's Fork	0	0	5	0	0	5	0	0	1	0	0	1	0.20
DBF04052736	Henry Fork	0	0	23	0	0	23	0	0	4	0	0	4	0.18
DBF04052737	Bear Branch	6	0	13	0	0	19	1	0	2	0	0	3	0.16
DBF04052738	Elk Creek	9	0	3	0	0	12	3	0	1	0	0	4	0.34
DBF04052739	Bear Creek	11	0	0	0	0	11	3	0	0	0	0	3	0.27
DBF04052740	Bear Creek	28	0	23	0	0	51	6	0	5	0	0	11	0.22

Table 10. Dominant and subdominant substrate types observed in pools (P; includes glides) and riffles (R; includes runs and cascades) during BVET habitat inventories at sample sites, Redbird District, July 2015 (see Appendix B for substrate class descriptions). The first number in each pair is for dominant substrate, the second for subdominant substrate. For example, in pools at the Spencer Branch sample site (DBF04052713), bedrock was dominant in 3 pools and subdominant in 0 pools.

Substrate Size Class	DBF04052713 Spencer Branch		DBF04052729 Sugar Creek		DBF04052730 Granny's Branch		DBF04052731 L. Fk Ulysses Cr.		DBF04052732 Ulysses Creek		DBF04052733 Couch Fork		DBF04052734 Bob's Fork	
	P	R	P	R	P	R	P	R	P	R	P	R	P	R
Organic matter	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Clay	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Silt	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sand	0,2	0,0	1,2	0,0	0,0	0,0	0,2	0,0	0,1	0,1	0,0	0,0	2,0	0,0
Small gravel	0,0	0,0	0,0	0,0	1,0	0,2	0,0	0,0	0,2	0,0	0,0	0,1	0,0	0,0
Large gravel	0,0	0,2	0,0	0,0	0,0	0,1	0,1	1,1	0,1	1,1	1,1	2,0	2,1	0,2
Cobble	0,0	0,0	2,0	2,1	0,1	3,0	1,1	0,2	0,0	0,2	0,1	0,2	0,2	2,1
Boulder	0,1	2,0	0,1	1,2	0,1	0,0	1,0	2,0	0,0	0,0	1,0	1,0	0,0	0,0
Bedrock	3,0	1,1	0,0	0,0	1,0	0,0	2,0	0,0	4,0	3,0	0,0	0,0	0,1	1,0

Table 10 continued.

Substrate Size Class	DBF04052735 Hal's Fork		DBF04052736 Henry Fork		DBF04052737 Bear Branch		DBF04052738 Elk Creek		DBF04052739 Bear Creek		DBF04052740 Bear Creek	
	P	R	P	R	P	R	P	R	P	R	P	R
Organic matter	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Clay	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Silt	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sand	0,1	0,0	0,1	0,0	1,0	0,0	1,0	0,0	0,0	0,0	0,1	0,0
Small gravel	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,0	0,1	0,0
Large gravel	1,1	0,2	0,0	0,0	0,0	1,0	1,2	1,2	0,1	0,0	0,0	0,0
Cobble	2,1	3,0	1,0	0,1	0,0	0,1	0,1	2,1	0,0	0,3	1,1	1,3
Boulder	1,0	1,2	0,0	1,0	1,0	0,1	0,0	0,0	0,0	3,0	1,2	3,1
Bedrock	0,0	0,0	0,0	0,0	0,1	1,0	1,0	0,0	2,0	0,0	3,0	0,0

Table 11. Riffle stability index results (Kappesser 2002), based on pebble count data collected at sample sites, Redbird District, 2015.

Site #	Stream Name	Riffle Stability	Bar Sample Geometric	Relative Bed	Log of Relative Bed	Median Particle Size			
		Index	Mean	Stability	Stability	D25	D50	D75	D84
DBF04052713	Spencer Branch	51.2	114.9	0.92	-0.04	24	106	1,024	1,024
DBF04052729	Sugar Creek	65.7	105.8	0.53	-0.28	14	56	140	210
DBF04052730	Granny's Branch	83.8	123.1	0.26	-0.59	14	32	82	122
DBF04052731	Left Fork Ulysses Creek	83.2	115.8	0.31	-0.51	14	36	76	118
DBF04052732	Ulysses Creek	27.3	112.6	9.10	0.96	38	1,024	1,024	1,024
DBF04052733	Couch Fork	75.1	115.0	0.43	-0.36	18	50	112	170
DBF04052734	Bob's Fork	87.9	125.2	0.37	-0.43	18	46	90	112
DBF04052735	Hal's Fork	79.4	122.3	0.38	-0.42	20	46	104	150
DBF04052736	Henry Fork	83.0	107.2	0.30	-0.53	10	32	76	110
DBF04052737	Bear Branch	35.4	116.9	8.55	0.93	52	1,000	1,024	1,024
DBF04052738	Elk Creek	67.2	99.4	0.52	-0.28	18	52	130	1,024
DBF04052739	Bear Creek	74.7	108.2	0.46	-0.34	22	50	108	240
DBF04052740	Bear Creek	81.0	100.1	0.34	-0.47	8	34	76	112

Appendix A: Field Methods for Stream Inventory

Sampling Strategy

Day 1 – Macroinvertebrate collection & BVET Inventory

- All team to first site to learn site documentation, site layout, and macroinvertebrate and habitat sampling methods
- While 2 team members conduct the BVET inventory and site layout, 2 or more other team members can collect macroinvertebrates
- Split into several teams (depending on team size) to visit and document other sites, layout sites, and sample macroinvertebrates and habitat

Day 2 – Efish & Pebble Counts

- Perform efish, pebble, and bar-count sampling at sites visited on day 1
- If the team is large enough, the team can split so that two teams are continuing with site documentation, site layout, macroinvertebrate, and habitat sampling methods

Day 3

- Continue with approach from day 2, allowing at least 1 day between macroinvertebrate and fish sampling
- If the fish sampling team catches up with the layout team, then take a day to split into several layout teams as during day 1
- When layout team finishes all sites they can rejoin fish sampling team

This approach should maximize team efficiency and prevent biases associated with sampling fish and macroinvertebrates within the same site in the same day.

Site Documentation

Objective - Record location and description of site for reporting purposes

Methods

- Directions to site
 - Record roads taken to parking area
 - Record trails walked to site
 - Document route to site on quadrangle map
- GPS
 - Record GPS coordinates at start and end of inventory
- Photos
 - Take digital photo from downstream end looking up, upstream end looking down
 - Photograph any pertinent features within the site that may influence habitat and fauna, example, road or trail crossings, erosion, etc.
- Written description
 - Record comments on land use in the site area, for example private land with mowed lawns, all forested, pasture lands, etc.
 - Record comments on other features that may be influencing stream conditions

Site Layout

Objective - Use consistent method to lay out site for fish and macroinvertebrate sampling

Methods

- Locate 1 – 2 riffles or runs and determine the average wetted width by making several measurements and computing the average. Measure width perpendicular to thalweg.
 - If the average wetted width is less than or equal to 3.0 m, then the site length will be 120 m
 - If the average wetted width is greater than or equal to 7.5 m, then the site length will be 300 m
 - If the average wetted width is between 3.0 and 7.5 m, then site length is 40-times the average wetted width, example: average wetted width = 5 m; site length = $5 \times 40 = 200\text{m}$
- Hang a double orange flag at the downstream end of the site. Attach topofil from a hipchain and walk to the midpoint of the site, hang a single orange flag, then continue to the end of the site and hang another single orange flag (hanging the flags to layout the site can be done while performing the BVET inventory)
- Record the average wetted width and site length on the datasheet
- Sites will not be moved to avoid road or trail crossings – moving sites violates the assumptions of the stratified random sample design and invalidates statistical analysis. Document these features fully with photos and written descriptions
- Always begin sites at the downstream end of a defined habitat unit, end points should be at the exact distance as described above
- In large streams make sure the site includes all of a fast water habitat unit and all of a slow water habitat unit

Habitat Inventory (BVET)

Objective – Characterize stream habitat attribute within the sample site.

Methods

- Collect attribute as described in Section 2 of Roghair and Nuckols (2005) (Appendix B)
- Increase frequency of paired (sub-) samples to include at least 3 fast and 3 slow water units within each site
 - Where less than 3 fast or slow occur, sub-sample all units
- Start and end data collection at habitat unit breaks
 - This may extend habitat data collection slightly beyond end of sample site (however, still hang site-end flag at calculated distance, not at the upper end of habitat unit)

Macroinvertebrates Inventory

Objective - Collect assemblage sample

Methods

- Using D-frame nets and a seine collect macroinvertebrates using the riffle sample and multi-habitat sample methods described by KDOW (2011)
- Where possible, keep macroinvertebrate samples within designated sites. If this is not possible be sure to indicate on datasheet.

Kentucky Division of Water (KDOW). 2011. Methods for sampling benthic macroinvertebrate communities in wadeable waters. Kentucky Department for Environmental Protection. Division of Water, Frankfort, KY.

Electrofishing Inventory

Objective - Determine relative abundance and determine catch-per-unit-effort (CPUE). Note: we are not attempting to estimate population size or density for individual species, only assessing the fish assemblage

Methods (based on sampling strategies discussed and approved by R8 and SRS personnel in 3/2005)

- Electrofishing starts in same location as habitat inventory
- Electrofishing ends at location designated in site layout process
 - Habitat inventory may extend beyond end of designated site
 - DO NOT extend electrofishing sample beyond end of designated site
- Single-pass DC backpack electrofishing
- One shocker, 3 netters (a net on the probe can be the 3rd net)
- No blocknets
- Electrofishing effort will be equal to 1.0 seconds for each 1.0 m² of wetted area
 - note: this will standardize our effort and remove the potentially confounding effect of changes in wetted width relative to the bankfull channel width in wet or dry years
 - derived Warren et al. data on electrofishing effort in MS streams
- Fish will be counted and released at the site, except for a voucher specimen for each species; endangered species lists will be reviewed before sampling
- Record age-0 fish and all fish older than age-0 separately for each species
- Keep all relic mussel shells encountered
- Record number of crayfish captured (don't actively net crayfish, but bucket any that end up in the net). If also vouchering fish then keep a couple crayfish specimens (ideally Form I & II males)

Pebble Count Inventory

Objective - Determine the riffle stability index (RSI), bar sample geometric mean, and median particle sizes.

Methods

- Pebble count data is collected using methods modified from those in Kappesser (2002) to characterize the substrate composition of sample sites
- Pebble counts are performed in riffles designated for electrofishing by walking transects perpendicular to the flow within the bankfull channel (Harrelson et al. 1994)
- Walk the transect beginning at the edge of the bankfull channel on one side of the stream and walk heel-to-toe across the stream channel to the opposite bank
- At each step pick up the pebble at the tip of your toe and measure its intermediate axis with a ruler to the nearest millimeter
- For very large particles, the same particle is counted as many times it is encountered
- These procedures are repeated until at least 200 measurements are recorded; Transects are not terminated until the opposite bank is reached even if this results in more than 200 measurements
- Transects are distributed throughout the riffle; If detritus, LW, or other organic materials are encountered the rock substrate found directly below them is sampled
- For the bar sample, measure 30 freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above; Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles
- The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars; The entire bar should be visually inspected to identify the dominant large size of particle present; If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle; For each particle, measure the intermediate axis to the nearest millimeter

Bunte, K. and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadeable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Harrelson, Cheryl C., Rawlins, C. L., and Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Kappesser, G. B. 2002. A riffle stability index to evaluate sediment loading to streams. Journal of the American Water Resources Association. 38:1069-1081.

Appendix B: Field Methods for Habitat Inventory

**Guide to Stream Habitat Characterization using the BVET Methodology
in the Daniel Boone National Forest, KY**



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Manual Revised - June 2011

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Introduction

The Basinwide Visual Estimation Technique (BVET) is a versatile tool used to assess streamwide habitat conditions in wadeable size streams and rivers. A team of two individuals performs the inventory using two-stage visual estimation techniques described in Hankin and Reeves (1988) and Dolloff et al. (1993). In its most basic form the BVET combines visual estimates with actual measurements to provide a calibrated estimate of stream area with confidence intervals, however the team may inventory any number of other habitat attributes as they walk the length of the stream. Experienced teams can inventory an average of 2-3 km per day, but this will vary depending on stream size and the number of stream attributes inventoried.

Before a team begins a BVET inventory they must receive adequate training, both in the classroom and in the field. Estimating and measuring a large number of habitat attributes can confuse and overwhelm an inexperienced team. Individuals must have an understanding of the basic concepts behind the BVET and be familiar with habitat attributes before they can effectively and efficiently perform an inventory.

In summer 2004, resource managers on the Daniel Boone National Forest (DBNF) requested that the USFS Center for Aquatic Technology Transfer (CATT) implement modified BVET inventories to inventory stream sites previously inventoried in the 1990's. The 1990's inventories followed methods detailed in the 'Daniel Boone National Forest Stream Inventory Work Plan and Sampling Techniques Manual', which were similar in nature to the BVET habitat inventory. After discussion with resource managers from the DBNF, we scaled down the original protocol, eliminating several attributes and modifying others to maximize inventory efficiency during our limited time on the Forest. In summer 2005 the DBNF opted to use identical BVET methods as National Forests in Virginia and North Carolina, which are only slightly different from methods used in Kentucky in 2004.

This document was developed to serve as a guide for classroom and field instructions specific to the ONF BVET habitat inventory and to provide a post-training reference for field teams. It includes an overview of the BVET inventory, defines habitat attributes, instructs how and when to measure attributes, and provides reference sheets for use in the field. Each trainee should receive a copy of this manual and is encouraged to take notes in the spaces provided.

We used an abbreviated version of the BVET to sample habitat within sample sites only. Paired samples were collected more frequently than described here because sample sites were short. Stream attributes were collected as described in Section 2.

References cited in this manual:

- Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.
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- Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.
- Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.
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Outline of BVET Habitat Inventory

1. Enter 'Header' information on the data sheet: --- 'Header' information includes date, stream, start location, team, etc. and is **vital** important to record for future reference.
2. Enter downstream of the starting point, then move upstream and begin the inventory. Tie off the hipchain, proceed upstream to the starting point, reset the hipchain to zero, and proceed upstream estimating parameters and recording data in every habitat unit.
3. At the paired sample units perform visual estimates, then perform measurements. Pair a minimum of 3 fast and 3 slow water units; pair more if possible.
4. Progress upstream estimating attributes for every unit until the next paired sample unit is reached, then repeat step 4.

The team should also take care to record roads, trails, tributaries, dams, waterfalls, road crossing types, riparian features (wildlife openings, trails, campsites, roads, timber harvest, etc.), and other pertinent stream features as they progress upstream. Be sure to record hipchain distances when noting such features. Some features may also require a picture number to be associated with them.

The following sections describe the BVET habitat inventory in detail:

Section 1: Getting Started – equipment, header info, random numbers, starting the inventory

Section 2: Habitat Attributes – definitions, how to estimate or measure, when to record

Section 3: Wrapping Up – what to do when the inventory is completed

Section 4: Summary

Section 5: GPS Instructions

Appendix: field guide, random number tables, equipment checklist

Section 1: Getting Started

Equipment List

- | | |
|--|---|
| <input type="checkbox"/> Hipchain | <input type="checkbox"/> Camera |
| <input type="checkbox"/> Extra string for hipchain | <input type="checkbox"/> Backpack |
| <input type="checkbox"/> Wading rod | <input type="checkbox"/> Pencils |
| <input type="checkbox"/> 50 m tape measure | <input type="checkbox"/> Flagging |
| <input type="checkbox"/> Clinometer | <input type="checkbox"/> Markers |
| <input type="checkbox"/> Datalogger | <input type="checkbox"/> Waterproof backup datasheets |
| <input type="checkbox"/> Thermometer | <input type="checkbox"/> Clipboard |
| <input type="checkbox"/> GPS unit | <input type="checkbox"/> BVET field guide on waterproof paper |
| <input type="checkbox"/> Topographic map w/NHD_ID | <input type="checkbox"/> Felt bottom wading boots or waders |
| <input type="checkbox"/> Cell Phone | <input type="checkbox"/> Water |
| <input type="checkbox"/> First Aid Kit | <input type="checkbox"/> Water Filter |
| <input type="checkbox"/> Rain Gear (optional) | <input type="checkbox"/> Toilet Paper |

The BVET team consists of two individuals, the ‘observer’ and the ‘recorder’. The observer wears the hipchain and carries the wading rod. The recorder wears the data logger and carries other equipment in the backpack. The duties of each individual are listed below.

Duties

Observer	Recorder
Designate habitat units	Locate changes in NHD_ID
Measure distance	Record data
Estimate width	Determine paired sample location
Estimate depths	Classify and count Large Wood (LW)
Classify substrates	Photo-documentation
Locate features	Document features
Estimate percent fines	GPS-documentation

Both team members are needed to measure actual widths, channel widths, riparian areas, gradient, and water temperature at designated units. Although the team has assigned duties, they should not hesitate to consult with each other if they have questions or feel that a mistake may have been made. Working as a team will provide the best possible results.

Header Information

Header information is **vitaly important** for future reference. Take the time to record all categories completely and accurately.

Stream Name	Full name of stream
District	National Forest District name
Quad	USGS 1:24,000 quadrangle name
Date	Record date(s) of inventory
Recorder	Full name of recorder
Observer	Full name of observer
GPS	Record at start and end locations, always use NAD83 CONUS, UTM
Location	Detailed written description of start point, include landmarks, road #, etc.
Comments	Record signs of activity in area, water conditions, other pertinent information

Starting the Inventory

After the team has organized their gear, determined their measurement interval, selected a random number, and recorded all the header information they are ready to begin the habitat inventory.

The observer should enter the stream slightly downstream of the starting point, tie off the hipchain, progress upstream to the starting point, reset the hipchain to zero and begin walking upstream through the first habitat unit. As the observer moves upstream they use the wading rod to measure depth at several locations in the habitat unit and make observations of unit type, width, substrates, and percent fines. When they reach the upstream end of the habitat unit they stop, turn to face the unit and report the unit type, maximum and average depth, riffle crest depth (where appropriate), dominant and subdominant substrate classes, percent fines, estimated width, and hipchain distance to the recorder.

As the observer moves upstream through the unit, the recorder follows behind, recording the amount of LW in the habitat unit. The recorder also assigns a number to the habitat unit. The recorder tells the observer if a unit is designated for measurements (i.e. if it is a 'paired sample' unit) only after they have recorded visual estimates.

The team continues upstream making estimates in every habitat unit and making estimates and measurements in every paired sample unit until the inventory endpoint is reached.

Definitions of habitat attributes, how to measure and when to record them, and what to do when the inventory is complete are covered in the following sections.

Section 2: Stream Attributes

Unit Type (see abbreviations)

Unit Type	Abbreviation	Definition
Riffle	R	Fast water, turbulent, gradient <12% ; shallow reaches characterized by water flowing over or around rough bed materials that break the surface during low flows; also include rapids (turbulent with intermittent whitewater, breaking waves, and exposed boulders), chutes (rapidly flowing water within narrow, steep slots of bedrock), and sheets (shallow water flowing over bedrock) if gradient <12%
Cascade	C	Fast water, turbulent, gradient ≥12% ; highly turbulent series of short falls and small scour basins, with very rapid water movement; also include sheets (shallow water flowing over bedrock) and chutes (rapidly flowing water within narrow, steep slots of bedrock) if gradient ≥12%
Run	RN	Fast water, non-turbulent, gradient <12% ; deeper than riffles with little or no surface agitation or flow obstructions and a flat bottom profile
Pool	P	Slow water, surface turbulence may or may not be present, gradient <1%; generally deeper and wider than habitat immediately upstream and downstream, concave bottom profile; includes dammed pools, scour pools, and plunge pools
Glide	G	Slow water, no surface turbulence, gradient <1% ; shallow with little to no flow and flat bottom profile
Underground	UNGR	Stream channel is dry or not containing enough water to form distinguishable habitat units

*modified from Armantrout (1998)

How to estimate:

Habitat units are separated by ‘breaks’. Breaks can be obvious physical barriers, such as a debris dam separating two pools or a small waterfall separating a pool and riffle, or may be less obvious transitional areas. Questions often arise as to whether a break is substantial enough to split two habitat units and where the exact location of the break occurs. When in doubt, the observer should consult with the recorder and the team should ‘think like a fish’. To determine if a break should be made, consider whether a fish would have to make an effort to move across the break and into the next habitat unit. If not, then it is probably a single habitat unit.

The channel may have both pool and riffle type habitat in the same cross-sectional area. Determine the predominate habitat type and record it as the unit type. For example if an area contains both pool and riffle, but the majority of the flow is into and out of the pool habitat, then call the unit a pool.

Questions also often arise as to the minimum size of individual habitat units. Generally, if a habitat unit is not at least as long as the wetted channel is wide, then do not count it as a separate habitat unit. This rule may need to be adjusted for streams wider than 5 m. Use best professional judgment in such cases.

See the section 2.1 for a list of features that should also be recorded while performing the inventory.

When to record: every habitat unit

Unit Number (#)

Definition:

Count of habitat units of similar types, used to determine location of paired sample units

How to estimate:

When counting habitat units, group pools and glides (slow water) together, and group riffles, runs, and cascades (fast water) together. For example, consider the following sequence of habitat units:

Pool – Riffle – Pool – Pool – Riffle - Cascade – Riffle - Glide – Riffle – Pool – Run – Pool – Riffle

Habitat units in this sequence would be counted in the following manner (similar types are shaded same color):

Unit Type	Unit Number
P	1
R	1
P	2
P	3
R	2
C	3
R	4
G	4
R	5
P	5
RN	6
P	6
R	7

In the above example, the team has counted six slow water (pool/glide) units and seven fast water (riffle/run/cascade) units.

When to record: every habitat unit; not recorded for features

Distance (m)*Definition:*

Number of meters (rounded to the whole meter) from the start of the inventory to the upstream end of the habitat unit or distance from the start of the inventory to upstream end of a feature, used as spatial reference for data analysis and to locate features in the future.

How to estimate:

The observer walks upstream in the middle of the stream channel with a hipchain measuring device. When they reach the upstream break between habitat units or the upstream end of a feature they stop and report the distance to the recorder.

Care should be taken to keep the hipchain string in the middle of the stream, especially around bends and meanders. If the hipchain should break, retreat to the location where the break occurred, tie off the hipchain, and continue. If the hipchain is reset for any reason be sure to note it in the comments.

When to record: every habitat unit and feature

Estimated Width (m)*Definition:*

Average wetted width of the habitat unit as estimated visually (typically to half-meter accuracy), used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to estimate:

The observer notes the general shape and width of the unit while walking to the upstream end. When they reach the upstream end of the unit the observer stops, turns to face the unit, and estimates the average wetted width. Measure the wetted width of the stream before starting each day to calibrate yourself.

When to record: every habitat unit

Maximum and Average Depth (cm)

Definitions:

Maximum Depth – vertical distance from substrate to water surface at deepest point in habitat unit

Average Depth – average vertical distance from substrate to water surface in habitat unit

How to estimate:

The observer uses a wading rod marked in 5 cm increments to measure water depth as they walk upstream through the habitat unit. Water depth in deepest spot is recorded as the maximum depth. Average depth is the average of several depth measurements taken throughout the habitat unit.

When to record: every habitat unit

Riffle Crest Depth (cm)

Definition:

Vertical distance from the substrate to the water surface at the deepest point in the riffle crest. The riffle crest is the shallowest continuous line (usually not straight) across the channel where the water surface becomes continuously riffled in the transition area between a riffle (or a run or cascade) and a pool (or glide) (Armantrout 1998); think of it as the last place water would flow out of the pool if the riffle ran dry.

How to estimate:

When the observer reaches the upstream end of a riffle (or a run or cascade) leading into a pool (or glide), they use the wading rod to measure the deepest point in the riffle crest. Record the depth in the RCD column for the riffle habitat row.

When to record: at the upstream end of any riffle, run, or cascade leading into a pool or glide

Dominant and Subdominant Substrate (1-9)

Definitions:

Dominant Substrate – size class of stream bed material that covers the greatest amount of surface area within the wetted channel of the habitat unit.

Subdominant Substrate – size class of stream bed material that covers the 2nd greatest amount of surface area within the wetted channel of the habitat unit.

How to estimate:

The following size classes are used to categorize substrates*. The substrate 'Number' is entered into the dominant and subdominant substrate columns on the datasheet.

Type	Number	Size (mm)	Description
Organic Matter	1		dead leaves, detritus, etc. – not live plants
Clay	2		sticky, holds form when rolled into a ball
Silt	3		slippery, does not hold form when rolled into a ball
Sand	4	silt – 2	grainy, does not hold form when rolled into ball
Small Gravel	5	3-16	sand to thumbnail
Large Gravel	6	17-64	thumbnail to fist
Cobble	7	65-256	fist to head
Boulder	8	>256	larger than head
Bedrock	9		solid rock, parent material, may extend into bank

* these size classes are based on the modified Wentworth scale

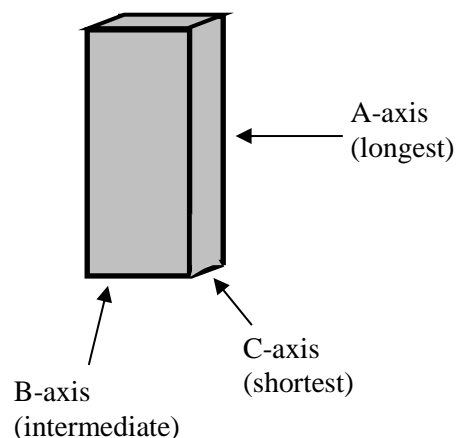
As the observer walks through the unit they scan the substrate. When they reach the upstream end of the unit they stop, turn to face the unit, and determine the dominant and subdominant substrate classes.

Estimate substrate size along the intermediate axis (b-axis). The b-axis is not the longest or shortest axis, but the intermediate length axis (see below). It is the axis that determines what size sieve the particle could pass through. Remember that your eyes are naturally drawn to larger size substrates. Be careful not to bias your estimate by focusing on the large size substrate.

Some units will contain a mixture of particle sizes. Consult with the recorder and use your best professional judgment to choose the dominant and subdominant sizes.

In units where the substrate is covered in moss, algae, or macrophytes classify the underlying substrate and make note of the plant growth in the comments. Only call organic substrate where there is dead and down leaves or other detritus covering the bottom of the unit.

When to record: every habitat unit



Rosgen Channel Type (A-G)

Definitions:

Stream channel classification system described in Rosgen (1996) based on entrenchment, width/depth ratio, sinuosity, and percent slope

How to Measure:

Before the team begins the inventory they should make the measurements described below to determine the channel type. Channel types are based on the following channel characteristics:

	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Sinuosity	1 – 1.2	> 1.2	> 1.2	n/a	> 1.5	> 1.2	> 1.2
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Although we record channel type for every unit, it was designed to describe a reach of stream. Our main objective here is to locate changes between channel types, which could either be abrupt (such as change from a B to a G near a road crossing) or less obvious transitional areas (such as a natural transition from a B to an A channel as you move upstream). If you think channel type may have changed take the time to make the calculations listed below to determine the channel type for the reach you are entering.

Full channel type descriptions and how to measure each of the channel characteristics in the table above can be found in Rosgen (1998). Never perform measurements in a pool, always attempt to find a run or deep riffle with well-defined bankfull indicators to perform measurements. A summary of each is listed below:

Entrenchment (page 31 & 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width the maximum bankfull depth
- stretch a tape across the channel at 2x the maximum bankfull depth (this is the flood prone area)
- divide the flood prone area width by the bankfull width to determine entrenchment ratio

Width to Depth Ratio (page 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width and the maximum bankfull depth
- divide bankfull width by depth to determine width to depth ratio

Sinuosity (need aerial photo to determine)

Slope (page 37 in Rosgen field guide):

- Measure riffle to riffle gradient using clinometer

When to measure: every paired fastwater habitat unit*

* record for every fastwater paired unit, but remember this is describing a reach characteristic – see above

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Percent Fines (%)

Definition:

Percent of the total surface area of the stream bed in the wetted area of the habitat unit that consists of sand, silt, or clay substrate particles (i.e. particles < 2 mm diameter).

How to estimate:

As the observer walks through the habitat unit they note the amount of sand, silt, and clay in the habitat unit. When they reach the upstream end of the unit, they stop, turn to face the unit and estimate the amount of the total surface area within the wetted channel that consists of sand, silt, or clay.

Where to estimate: every habitat unit

Large Wood (1-4 and rootwad)

Definition:

Count of dead and down wood within the bankfull channel of a habitat unit

How to estimate:

The recorder classifies and counts LW as they walk through the habitat unit. LW counts are grouped by the size classes listed below:

Category	Length (m)	Diameter (cm)	Description
1	1-5	10-55	short, skinny
2	1-5	>55	short, fat
3	>5	10-55	long, skinny
4	>5	>55	long, fat
RW	rootwad	rootwad	roots on dead and down tree

Only count wood that is:

- 1 m in length and > 10.0 cm in diameter
- Within the bankfull channel
- Fallen, not standing dead

Additionally:

- Count rootwads separately from attached pieces of LW
- Estimate the diameter of LW at the widest end of the piece
- A piece that is forked, but is still joined counts as only one piece of LW
- Only count each piece one time, do not count a piece that is in two habitat units twice
- Enter the total count for each size category into the appropriate column on the datasheet

Where to estimate: every habitat unit

Actual Width (m)*Definition:*

Average wetted width of the habitat unit as measured with 50 m tape, used to calculate stream area.

Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to measure:

Use a meter tape to measure the wetted width of the stream in at least three locations. Average the measurements to obtain the average wetted width.

Where to measure: paired sample habitat units

Bankfull Channel Width (m)*Definition:*

Actual width of channel at bankfull elevation as measured with meter tape. Depending on channel type, bankfull may or may not be represented by the top of the banks. Use bankfull indicators to locate the top of the bankfull channel (Rosgen 1996).

How to measure:

Determine the location of bankfull water depth on both banks of the habitat unit and measure across the channel perpendicular to flow from bankfull to bankfull.

Where to measure: paired sample riffles, runs, or cascades

Riparian Width (m)

Definition:

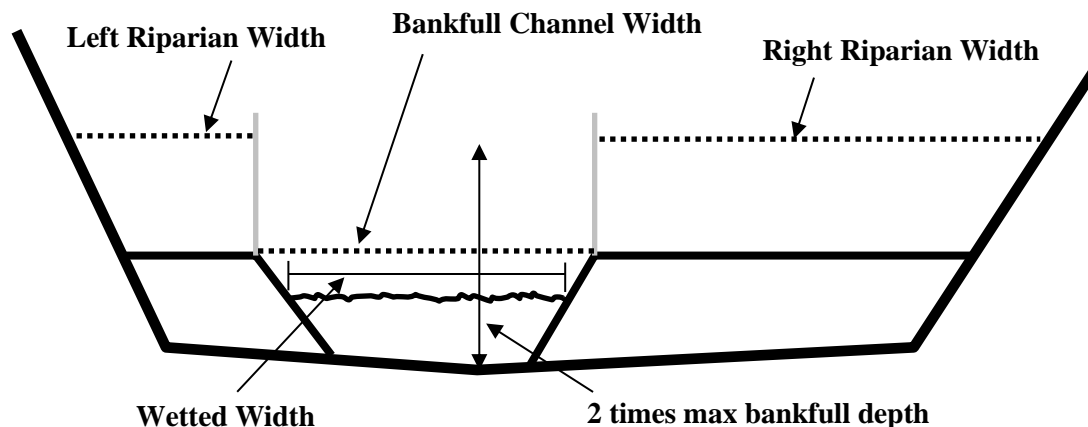
Width of the riparian area at an elevation of two times the maximum bankfull depth, measured for both left and right banks (left and right as oriented facing upstream). Maximum bankfull depth is the greatest vertical distance from the substrate to the top of the bankfull channel across a bankfull transect.

How to measure:

- Stretch a measuring tape across the top of the bankfull channel – this is your bankfull transect
- Use a wading rod to find the maximum bankfull depth
- Place the clinometer against the wading rod at two-times the maximum bankfull depth
- Using the clinometer to maintain a slope of zero degrees, site perpendicular to the channel to the intersection with the nearest landform. It may be necessary to site to an intermediate point, move the wading and clinometer, and site again if the tape measure is too short or the view is obstructed
- Measure the distance from the edge of the bankfull channel to the landform – do this separately for the left and right (as facing upstream) riparian areas

Note: if riparian width is more than 50 m, record 51 as the riparian width and note in ‘Comments’ that riparian width was longer than meter tape

Where to measure: paired sample riffles, runs, or cascades



Gradient (%)

Definition:

Change in vertical elevation per unit of horizontal distance of the water surface (Armantrout 1998)

How to measure:

Gradient is measured in riffles with a clinometer using the following steps:

- Observer stands at upstream end of riffle, recorder stands at downstream end of riffle
- Recorder sites upstream to the height of their eye on the observer using clinometer
- Record the **percent** slope, **not the degrees** (tip the clinometer all the way back to determine which side of the scale is percent)

The recorder should determine the height of their eye on the observer at the beginning of the inventory. Be certain that the observer and recorder are standing with their feet in the same position (preferably with feet at top of water surface) within the stream channel. If the observer is standing on top of a boulder and the recorder is standing in a depression, the measured gradient will be incorrect.

Where to measure: paired sample riffles, runs, or cascades

Water Temperature (C)

Definition:

Temperature of the water in degrees Celsius.

How to measure:

Place the thermometer in moving water in an area not exposed to direct sunlight. Leave the thermometer sit for at least three minutes, then record the water temperature in degrees Celsius.

Where to measure: paired sample riffles, runs, or cascades

Photo (ID#)

Definition:

Photograph of habitat unit or crossing feature.

How to measure:

Take photo facing upstream with observer holding wading rod in picture. Be sure to get entire width (and length if possible) of habitat unit or crossing feature in the photo.

Where to measure: paired sample riffles, runs, or cascades and any crossing features encountered

Features

Definition: Points on a stream that could potentially serve as landmarks, may be natural or manmade.

How to measure: Record the distance to the upstream end of all features and take a photograph of all crossing features.

Where to record: wherever found

Channel Feature	Abbreviation	What to Record
Waterfall ¹	FALL	Distance, estimated height
Tributary	TRIB	Distance, average wetted width, into main channel on left or right (as facing upstream)
Side channel ²	SCH	Distance, average wetted width, whether it is flowing into or out of main channel on left or right (as facing upstream)
Braid ³	BRD	Distance at start and distance at end; continue with normal inventory up channel with greatest discharge
Seep (Spring)	SEEP	Distance, left or right bank (as facing upstream), size, coloration
Landslide	SLID	Distance, left or right bank (as facing upstream), estimated size
Other	OTR	Distance, description of feature, <i>example:</i> found water intake pipe going to house here; old burned out shack on side of stream; Big Gap campground on left; alligator slide here, etc.

¹ must be vertical with water falling through air to be a waterfall and not a cascade, do not record unless >1m high

² two channels, continue with normal inventory up channel with most volume

³ three or more channels intertwined, continue with normal inventory up channel with most volume

Crossing Feature	Abbreviation	What to Record*
Bridge	BRG	Distance, width, height, road or trail name and type (gravel, paved, dirt, horse, ATV, etc.), photo
Ford	FORD	Distance, road or trail name and type (gravel, paved, dirt, etc.), photo
Dam	DAM	Distance, type, condition, estimated height, dam use, name of road or trail, if applicable; include beaver dams, photo
Culvert	V	Distance, road or trail name, type, # of outlets, diameter/width, height, material, perch (distance from top of water to bottom lip of culvert, natural substrate (present or absent through length)), photo

* photograph all crossing features with person and wading rod for scale, record 'Y' in 'Photo' column

We cannot stress enough the importance of fully and accurately describing features. This means getting out a quadrangle map and finding road, trail, and tributary names and recording them in 'Comments' and taking the time to describe the location of features in relation to landmarks found on quadrangle maps.

Take photos of all crossing features!

Section 3: Wrapping Up

End the inventory where:

- Forest Service property ends
- Stream is dry for more than 500 m
- Stream channel is < 1.0 m wide for more than 500 m

Record the following in the Comments:

- Time and date
- Reason for ending the inventory
- Detailed written description of location using landmarks for reference
- **Be sure the header information is completed – GPS, etc**

When you return to home base:

- Immediately download the data and check file to be sure all data downloaded
- Check header information to be sure it is complete
- Save to the computer and create a backup copy
- Document any photographs
- If using paper, make a photocopy of the data and store in secure location

Section 4: Summary

Before starting:

- fill in header information

Record for every habitat unit:

- Unit Type
- Unit Number
- Distance
- Estimated Width
- Maximum Depth
- Average Depth
- Dominant Substrate
- Subdominant Substrate
- Percent Fines
- Large Wood

Record for every riffle, run, or cascade leading into a pool or glide:

- Riffle Crest Depth

Record for every paired sample pool:

- Measured Width

Record for every paired sample riffle:

- Measured Width
- Bankfull Channel Width
- Riparian Width (left and right)
- Gradient
- Rosgen Channel Type
- Water temperature
- Photograph

Record features and full feature descriptions wherever they are encountered.

Photograph all crossings!

Section 5: GPS Instructions

Garmin BVET Waypoint Labels:

Garmin BVET Waypoint Label Examples:

S123 **Start** location of BVET survey

E123 **End** location of BVET survey

123 = Site identification number

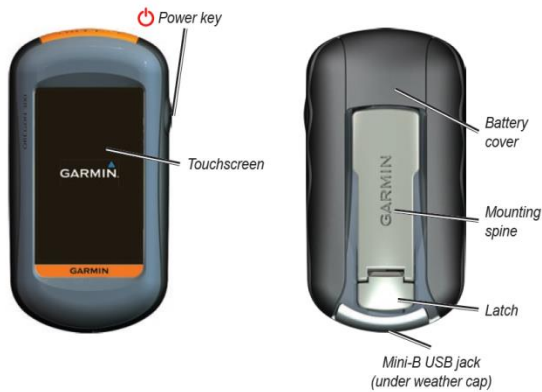
How to Find a Waypoint on GPS:

- Turn Power On.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the **Waypoints** icon with the red golf flag.
- At the bottom of the next screen touch the **ABC** pyramid button.
- Start typing in the name of the desired waypoint. Once the waypoint name is identified by the GPS it will list the waypoints associated with that waypoint name.
 - Note: Touch the left and right arrows at the bottom of the screen to move from letters to numbers to symbols. Touch the down arrow on the letters to get lowercase and up arrow to get back to uppercase.
- Touch the waypoint name you were looking for when the list pops up.
- To navigate to this location touch the big green **Go** button.

Changing Waypoints:

- To switch waypoints close the map screen by touching the **X** close button in the lower left corner of the screen.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the Stop Navigation button and repeat the top process to get to a new waypoint.

Garmin GPS Oregon 400T Cheatsheet



Turn On

- Press Power key, wait for GPS to boot

Turn Off

- Press and hold Power key

Backlight Strength

- Press and quickly release Power key, adjust with touchscreen options

Create New Waypoint

1. To create a waypoint of your current position touch *“Mark Waypoint”*
2. Touch *“Save and Edit”*, touch *“Change Name”*, type desired label, touch *“Green Check Icon”* to save

Calibrate compass

1. Whenever batteries are removed you must calibrate the compass so the map orients correctly
2. Touch *“Setup”*, touch *“Heading”*, touch *“Press to Begin Compass Calibration”*
3. Touch *“Start”*, hold GPS level and rotate it twice on your palm

Data Fields

1. To change the data fields on the map page touch *“Map”*
2. Touch a data field at the top of the map, then select your desired data field

Calibrating the Touchscreen

1. If the touchscreen buttons are not responding properly, recalibrate the touchscreen
2. While the GPS is turned off, press and hold the power key for ~30 seconds
3. Follow instructions on the screen until calibration is complete

Appendix: Field Guide, Equipment Checklist, Rosgen Worksheet

Record for every habitat unit:

- **Unit Type** – pool, riffle, run, cascade, glide, feature (see below)
- **Unit Number** – group pools & glides; group riffles, runs, cascades
- **Distance (m)** – at upstream end of unit
- **Estimated Width (m)** – visual estimate of average wetted width
- **Maximum Depth (cm)** – deepest spot in unit
- **Average Depth (cm)** – average depth of unit
- **Dominant Substrate (1-9)** – covers greatest amount of surface area in unit
- **Subdominant Substrate (1-9)** – covers 2nd most surface area in unit
- **Percent Fines (%)** – percent of bottom consisting of sand, silt, or clay
- **Large Wood (1-4, RW)** – count of dead and down wood in the bankfull channel

Record for every riffle, run, or cascade leading into a pool or glide:

- **Riffle Crest Depth (cm)** – deepest spot in hydraulic control between riffle type habitat and pool type habitat

Record for paired sample pools:

- **Measured Width (m)** – measurement of average wetted width

Record for paired sample riffles:

- **Measured Width (m)** – measurement of average wetted width
- **Channel Width (m)** – measurement of bankfull channel width
- **Riparian Width (m)** – L&R, measurement of floodplain
- **Gradient (%)** – clinometer measurement of riffle slope
- **Water Temperature (C)** – temperature of water in Celsius
- **Rosgen** – channel type classification
- **Photo (y or n)** – picture of habitat unit or crossing feature

Unit Types

- **Riffle (R)** – fast water, turbulent, gradient $<12\%$; includes rapids, chutes, and sheets if gradient $<12\%$
- **Cascade (C)** – fast water, turbulent, gradient $\geq 12\%$, includes sheets and chutes if gradient $\geq 12\%$
- **Run (RN)** – fast water, little to no turbulence, gradient $<12\%$, flat bottom profile, deeper than riffles
- **Pool (P)** – slow water, may or may not be turbulent, gradient $<1\%$, includes dammed, scour, and plunge pools
- **Glide (G)** – slow water, no surface turbulence, gradient $<1\%$, shallow with little flow and flat bottom profile
- **Underground (UNGR)** – distance at upstream end, why dry

Features

- **Waterfall (FALL)** – distance, height
- **Tributary (TRIB)** – distance, width, in on L or R
- **Side Channel (SCH)** – distance, width, in or out on L or R
- **Braid (BRD)** – distance at downstream and upstream ends
- **Seep or Spring (SEEP)** – distance, on left or right, amount of flow
- **Landslide (SLID)** – distance, L or R, est. size and cause
- **Other (OTR)** – record distance, describe feature in comments
- **Crossing Features** – photograph and record the following:
 - **Bridge (BRG)** – distance, height, width, road or trail name & type
 - **Dam (DAM)** – distance, type, est. height, road or trail name & type
 - **Ford (FORD)** – distance, road or trail name & type
 - **Culvert (V)** – distance, type (pipe, box, open box, arch, open arch), size, material, natural substrate, perch, road or trail name

Substrates

- **Organic Matter** – dead leaves detritus, etc., not living plants
- **Clay** – sticky, holds form when balled
- **Silt** – slick, does not hold form when balled
- **Sand** – >silt-2mm, gritty, doesn't hold form
- **Small Gravel** – 3-16mm, sand to thumbnail
- **Large Gravel** – 17-64mm, thumbnail to fist
- **Cobble** – 65-256mm, fist to head
- **Boulder** – >256, > head
- **Bedrock** – solid parent material

Large Wood

- **#1** <5m long, 10-55cm diameter
- **#2** <5m long, >55cm diameter
- **#3** >5m long, 10-55cm diameter
- **#4** >5m long, >55cm diameter
- **RW** – rootwad, count separately from attached LW, record in comments, do not record wood <10cm diameter, <1m length

Rosgen Channel Types

Rosgen Channel Types	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Measuring Riparian Width (paired fast water units only)

- Place clinometer against the wading rod at two times max bankfull depth
- Use the clinometer as a level – keep the slope at 0.0 – and site to the nearest landform perpendicular to the channel
- Measure the distance from the edge of the bankfull channel to the intersection with the landform
- Do this for both the left and right banks
- If riparian width in more than 50 m, record 51 as the riparian width and in 'Comments' note that riparian was > 50 m wide

End inventory

- End the inventory when the calculated sample distance has been inventoried.

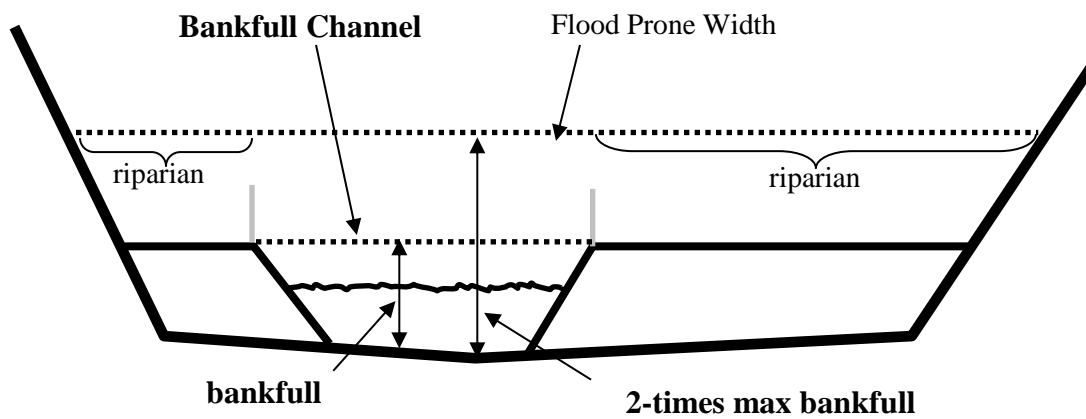
Equipment Checklist

- ☐ hipchain
- ☐ extra string for hipchain
- ☐ wading rod
- ☐ 50 m tape measure
- ☐ clinometer
- ☐ thermometer
- ☐ datalogger
- ☐ GPS unit
- ☐ camera
- ☐ backpack
- ☐ pencils
- ☐ flagging
- ☐ markers
- ☐ waterproof backup datasheets
- ☐ clipboard
- ☐ BVET field guide on waterproof paper
- ☐ topographic maps
- ☐ water
- ☐ water filter
- ☐ lunch
- ☐ first aid kit
- ☐ radio/cell phone
- ☐ toilet paper
- ☐ felt bottom wading boots
- ☐ raingear

Rosgen Measurements

All measurements should be made across a transect in an area of uniform flow, specifically riffle or run sections with few irregularities in cross-sectional shape. **Avoid** areas influenced by culverts, bridges, tributaries, side-channels, etc.

- What is the **entrenchment ratio**?
 - Entrenchment ratio = flood prone width / bankfull width
 - Floodprone width = width at two-times maximum bankfull depth
- What is the **width/depth ratio**?
 - Width/depth ratio = bankfull width / average bankfull depth
 - Be sure to use same units of measure (centimeters) for width and depth
 - Measure *bankfull* depth (**not** water depth) at several locations across transect to obtain average bankfull depth
- What is the **gradient**?
 - Measure riffle to riffle slope (%) with clinometer



Rosgen Worksheet

- A. Bankfull Channel Width (m) _____
- B. Maximum Bankfull Depth (cm) _____ *2 = _____
- C. Average Bankfull Depth (cm) _____
- D. Right Riparian Width (m) _____
- E. Left Riparian Width (m) _____
- F. Gradient (%) _____

$$\text{Entrenchment Ratio} = (A+D+E)/A$$

$$(\text{_____} + \text{_____} + \text{_____}) / \text{_____} = \text{_____}$$

$$\text{Width Depth Ratio} = (100*A)/C$$

$$(100* \text{_____}) / \text{_____} = \text{_____}$$

	A	B	C	D	E	F	G
Entrench. ratio	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Gradient (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

*these are the dominant ranges, values may be slightly outside these ranges

Appendix C: Field Methods for Macroinvertebrate Sampling

Macroinvertebrate Equipment List

- ☐ Mesh wash bucket
- ☐ Rinse bucket
- ☐ Squirt bottle
- ☐ Seine
- ☐ D-Frame nets
- ☐ PVC ¼ sq meter quadrates
- ☐ Tweezers
- ☐ Collection jars
- ☐ Sample labels
- ☐ Pencils
- ☐ Markers
- ☐ Ethyl alcohol

Macroinvertebrate Sampling Methods

1. Riffle Sample

- Take four 0.25 m² samples from midriffle or the thalweg (path of deepest thread of water).
- For each of the 4 samples, place a seine (600 µm mesh, one meter wide) in moderate to fast current in areas with gravel to cobble substrate. Place some rocks on the bottom edge of the seine to hold it on the channel bottom.
- Dislodge benthos by vigorously disturbing 0.25 m² (20 x 20 in.) in front of the net (use 0.25 m² PCV quadrate to sample correct area). Large rocks should be hand washed into the net.
- After each of the 4 samples is collected wash the contents of the net into a mesh wash bucket to prevent loss of inverts when collecting the next sample. All four samples are composited in the bucket.
- Find a suitable location on the side of the stream, spread the seine out on the ground, and wash the contents of the bucket onto the seine. With tweezers methodically sort through the sample picking out the invertebrates and placing them in a sample jar containing ethyl alcohol.
- The picking process can easily take an hour to complete; be patient and thorough. When complete be sure there is a sample label inside the jar as well as one on the outside.
- *This sample must be kept separate from all other subhabitat collections.*

2. Multi-Habitat Sample

- A. Sweep Sample** - Involves sampling a variety of non-riffle habitats with the aid of an 800 x 900 µm mesh D-frame dipnet. Each habitat is sampled in at least three (3) replicates, where possible.

- 1) *Undercut banks/root mats* - sampled by placing a large rootwad into the D-frame dipnet and shaken vigorously. The contents are removed from the dipnet and placed into a mesh wash bucket. Note: if undercut banks are present in both run and pool areas, each is sampled separately with three replicates.

- 2) *Marginal emergent vegetation* (exclusive of *Justicia americana* beds) – sampled by thrusting (i.e., “jabbing”) the dipnet into the vegetation for ca. 1 m, and then sweeping through the area to collect dislodged organisms. Material is then rinsed in the wash bucket and any sticks, leaves and vegetation are thoroughly washed and inspected before discarding.
- 3) *Bedrock or slab-rock habitats* - sampled by placing the edge of the dipnet flush on the substrate, disturbing approximately 0.1 m² of area to dislodge attached organisms. Material is emptied into a wash bucket.
- 4) *Justicia americana* (water willow) beds - sampled by working the net through a 1 m section in a jabbing motion. The material is then emptied into a wash-bucket and any *J. americana* stems are thoroughly washed, inspected and discarded.
- 5) *Leaf Packs* - preferably “conditioned” (i.e., not new-fall material) where possible; samples are taken from a variety of locations (i.e., riffles, runs and pools) and placed into the wash-bucket. The material is thoroughly rinsed to dislodge organisms and then inspected and discarded.

B. Silt, sand, and fine gravel

- 1) *Netting* - a D-frame dipnet is used to collect sand and silt depositional areas by placing the net on the substrate and vigorously stirring the sediments in front of the net. An area of 0.1 m² is sampled for each replicate making sure, where possible, that replicates are taken from different depositional areas.

C. Aufwuchs sample - small invertebrates associated with this habitat are obtained by washing a small amount of rocks, sticks, leaves, filamentous algae and moss into a medium-sized bucket half filled with water. The material is then elutriated and sieved with the nitex sampler.

D. Rock Picking - invertebrates are picked from 15 rocks (large cobble-small boulder size; 5 each from riffle, run and pool). Selected rocks are washed in a bucket half filled with water, then carefully inspected to remove invertebrates with fine-tipped forceps.

E. Wood Sample - pieces of submerged wood, ranging from roughly 3 to 6 meters (10 to 20 linear feet) and ranging from 5–15 cm (2–6 inches) in diameter, are individually rinsed into the wash-bucket. Pieces of wood are inspected for burrowers and crevice dwellers. Large diameter, well-aged logs should be inspected and handpicked with fine-tipped forceps.

Macroinvertebrate Sampling Summary

Sample	Sampling Device	Habitat	Replicates (composited)
1 Riffle*	Kick Seine/Mesh bucket/PVC Sq.	Riffle	4 - 0.25 m ²
2 Sweep - Undercut banks	Dipnet/Mesh Bucket	Undercut Banks/Roots	3
3 Sweep - Emergent vegetation	Dipnet/Mesh Bucket	Emergent Vegetation	3
4 Sweep - Bedrock	Dipnet/Mesh Bucket	Bedrock/Slabrock	3
5 Sweep - Justicia beds	Dipnet/Mesh Bucket	Justicia beds	3
6 Sweep - Leaf packs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
7 Silt,Sand, Fine Gravel	Dipnet/Mesh Bucket	Margins	3
8 Aufwuchs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
9 Rock Picking	Forceps	Riffle-Run-Pool	15 rocks (5-5-5)
10 Wood	Mesh Bucket	Riffle-Run-Pool	3-6 linear m

*Sample contents kept separate from other habitat samples.

Appendix D: Field Methods for Riffle Stability Index

Riffle Stability Index Field Methods

The Riffle Stability Index procedure is best applied to stream channels with gradients from 1.5 to 5 percent. The channel is best described as a Rosgen B-2, B-3, B-4 or F-2, F-3, F-4 type. Three riffles are measured within each uniform Rosgen reach. Each riffle selected for measurement should be representative or typical within the reach. An ideal riffle is located in a straight section of reach, has uniform depth in the cross-section, and is at a point of thalweg crossover. Flow is evenly distributed across the channel and is not concentrated toward either bank. For each riffle, field data are gathered to determine the distribution of particle sizes present. An estimate of the common large size of particle capable of movement at bankfull flow is obtained by sampling a nearby bar deposit.

1. Pebble Count - Particle Size Distribution on the Riffle

A particle size distribution is obtained on the riffle by a bed material sampling procedure called a "Wolman Pebble Count". A sample size of at least 200 is necessary for RSI. The sample points are identified by establishing a sampling grid over the riffle, with transects across the channel from bankfull to bankfull over the entire length of riffle. Samples are taken every foot along the transect. Thus, bankfull width in feet will equal the number of samples per transect. Dividing 200 by the number of samples per transect and rounding up will determine the number of transects needed. Spacing between transects is determined by dividing the length of riffle by the number of transects needed. For each sample, the intermediate axis of the particle is measured using a metric caliper, and is tallied by size class. For very large particles, count the same particle as many times as you encounter it. The cumulative percent finer is then calculated for each size class, and plotted on the graph.

2. Bar (Cobble) Count - Dominant Large Particles on a Bar

Measure 30 of the freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above. Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles. The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars. The entire bar should be visually inspected to identify the dominant large size of particle present. If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle. When this is done, a sample size of at least 20 is needed. For each of the particles, the intermediate axis is measured and recorded to the nearest millimeter. Calculate the arithmetic mean of the sample, and compare this with the plotted cumulative particle size distribution for the riffle. On the X axis, find the mean bar sample grain size. Go up to the cumulative particle size distribution, and read from the Y axis the percentile this represents. This percentile is the Riffle Stability Index.